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LRIT and AIS

An analysis of October 2010 data

Anna-Liesa S. Lapinski

Defence R&D Canada – Atlantic

Technical Memorandum

DRDC Atlantic TM 2012-234

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Canada

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Abstract

There have been amendments in the recent decade to Chapter V of the 1974 International Convention for the Safety of Life at Sea (SOLAS) which is concerned with Safety of Navigation. One amendment addressed collision avoidance, with the result being the automatic identification system (AIS). Another amendment addressed the identification and tracking of vessels at longer distances, with the result being the long-range identification and tracking (LRIT) system. The two systems have different purposes, but within those purposes they do provide similar information. The goals of this report include a better understanding of LRIT data, an understanding of how AIS and LRIT information complement each other and how combining AIS and LRIT information can improve maritime situational awareness. The AIS position information was found to be offset from the LRIT position information. Identifying vessels that are only broadcasting either AIS or LRIT but should be broadcasting both could be used to enforce AIS and LRIT regulations. It was found that using both systems to achieve situation awareness only offers limited redundancy; however, the two systems do complement each other. In coastal areas where no AIS data are being collected, requesting the LRIT reporting rate be increased could improve maritime situation awareness. Several of the findings documented in this paper corroborate findings made by the LRIT working group.

Résumé

Au cours des dix dernières années, des modifications ont été apportées au chapitre V de la Convention internationale de 1974 pour la sauvegarde de la vie humaine en mer (SOLAS), qui traite de la sécurité de la navigation. L'une des modifications portait sur les moyens d'éviter les collisions (évitement d'abordage); elle a donné lieu à la création du système d'identification automatique (SIA). Une autre modification portait sur la nécessité d'identifier et de suivre les navires sur de plus longues distances; cette modification a donné lieu à la création du système d'identification et de suivi à grande distance des navires (LRIT). Les deux systèmes ne jouent pas le même rôle, mais fournissent néanmoins des informations semblables. Le but du présent rapport est de mieux comprendre les données LRIT, de déterminer en quoi les systèmes SIA et LRIT se complètent et de trouver des façons de combiner l'information du SIA et celle du LRIT de manière à améliorer la connaissance de la situation maritime. L'information sur la position fournie par le SIA s'avère décalée par rapport à l'information sur la position fournie par le LRIT. L'identification des navires qui n'émettent que dans l'un ou l'autre des systèmes (SIA ou LRIT), mais qui devraient émettre dans les deux systèmes, pourrait servir à faire appliquer la réglementation sur le SIA et le LRIT. Il a été déterminé que l'utilisation des deux systèmes pour atteindre l'objectif de connaissance de la situation n'offre qu'une redondance limitée. Cependant, les deux systèmes se complètent l'un l'autre. Dans les zones côtières où aucune donnée SIA n'est recueillie, le fait de demander que la fréquence de transmission soit accrue pourrait améliorer la connaissance de la situation maritime. Plusieurs des résultats documentés dans le présent rapport confirment les résultats obtenus par le groupe de travail sur le LRIT.

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Executive summary

LRIT and AIS: An analysis of October 2010 data

Anna-Liesa S. Lapinski; DRDC Atlantic TM 2012-234; Defence R&D Canada – Atlantic; October 2014.

Introduction: On April 1, 2011, Defence Research and Development Canada (DRDC) started a new applied research project (ARP) in the Maritime Domain Awareness (MDA) thrust: *Situational Information for Enabling Development of Northern Awareness* (SEDNA) (11ho, 11jo). This is a 4-year R&D project with the goal of improving the ability to develop situational awareness in the Arctic, taking into account the vast and complex littoral environment, the harsh environmental conditions and the remote nature of Canada's north. The Long-Range Identification and Tracking system (LRIT) and the Automatic Identification System (AIS) are two systems that can be used to help improve maritime situational awareness in the Arctic, which is of increasing importance. As part of SEDNA, this study presents a detailed examination of LRIT. This work also considers how combining the AIS and LRIT information can improve maritime situational awareness. This study was done during the initial operational phase of LRIT, using one month of LRIT data. Results might not represent current operational capabilities.

Results: The October 2010 LRIT report analysis showed that LRIT and AIS data are complementary. The LRIT pre-scheduled reports were typically found to be within +/-5 minutes of the default 6 hour interval; though, there was also evidence of requests for vessels to report more frequently. In addition, there were occasions when the reports were late, were missing, or had incorrect/missing information. Given that the data set was from the initial operating phase of the LRIT system, this is almost expected. To the extent that they are redundant, AIS and LRIT can be used to identify vessels that are non-compliant in transmitting either AIS or LRIT. It was also observed that where a country is not receiving coastal AIS messages, they may consider increasing the reporting rates of LRIT broadcasting ships once they are within 6 hours of the coast.

Significance: LRIT data could become an important component of situational awareness in the arctic. In the absence of satellite AIS coverage and ground stations, LRIT would at least provide periodic position reports. Therefore, better understanding the data source was of significant importance.

Future plans: Develop several information products to help identify when ships are not adhering to AIS and LRIT rules, for example:

- Develop a product that uses AIS static information to determine if the vessel should also be broadcasting LRIT.
- Develop a product that triggers a database search of a vessel if it is only broadcasting LRIT in an area covered by AIS receivers, to determine if it is adhering to the AIS broadcast rules.
- Develop a product that generates a map every 6 hours or the last known position of all ships that missed their last LRIT pre-scheduled position report.

Sommaire

LRIT and AIS: An analysis of October 2010 data

Anna-Liesa S. Lapinski; DRDC Atlantic TM 2012-234; R & D pour la défense Canada – Atlantique; octobre 2014.

Introduction : Le 1er avril 2011, Recherche et développement pour la défense Canada (RDDC) a lancé un nouveau projet de recherche appliquée (PRA) s'inscrivant dans la foulée de la Vigilance dans le secteur maritime (VSM) : *Informations sur la situation pour permettre le développement des connaissances dans le Nord* (SEDNA, de l'anglais *Situational Information* for *Enabling Development of Northern Awareness*) (11HO, 11JO). Il s'agit d'un projet de R et D d'une durée de 4 ans, ayant pour but d'améliorer la capacité de développer la connaissance de la situation dans l'Arctique, en tenant compte du littoral vaste et complexe, des conditions environnementales difficiles et de l'éloignement du nord canadien. Le Système d'identification et de suivi à grande distance des navires (LRIT, de l'anglais *Long Range Identification and Tracking*) et le Système d'identification automatique (SIA) sont deux systèmes pouvant être utilisés pour améliorer la connaissance de la situation maritime dans l'Arctique, qui revêt une importance grandissante. Dans le cadre du SEDNA, cette étude présente une analyse détaillée du LRIT. Les travaux portent également sur la manière de combiner l'information du SIA et celle du LRIT de manière à améliorer la connaissance de la situation maritime. La présente étude a été réalisée durant la phase opérationnelle initiale du LRIT, en utilisant un mois de données du LRIT. Les résultats pourraient ne pas être représentatifs des capacités opérationnelles actuelles.

Résultats : L'analyse du rapport LRIT d'octobre 2010 a démontré que les données du LRIT et du SIA sont complémentaires. Les rapports prédéterminés du LRIT se situaient en général à +/-5 minutes de l'intervalle par défaut de 6 heures; cependant, il y avait également des signes de demandes à l'effet que les navires signalent leur présence plus fréquemment. De plus, dans certains cas, les rapports ont été soumis en retard, étaient manquants ou contenaient de l'information incorrecte ou encore il manquait de l'information. Étant donné que l'ensemble de données provenait de la phase opérationnelle initiale du système LRIT, on pouvait s'y attendre. Dans la mesure où ils sont redondants, le SIA et le LRIT peuvent être utilisés pour identifier des navires qui sont non conformes en ce qui a trait à la transmission d'information soit au SIA ou au LRIT. Il a également été observé que dans les cas où un pays ne reçoit pas de messages côtiers SIA, on pourrait envisager d'accroître la fréquence des rapports pour les navires émettant dans la zone LRIT une fois qu'ils se situent à moins de 6 heures de la côte.

Portée : Les données LRIT pourraient devenir une composante importante de la connaissance de la situation dans l'Arctique. En l'absence de couverture SIA par satellite et de stations terrestres, le LRIT permettrait au moins de fournir des rapports de position périodiques. Par conséquent, il était crucial de mieux comprendre la source de données.

Recherches futures : Élaborer plusieurs produits d'information permettant de déterminer les cas de non-respect des règles du SIA et du LRIT par les navires, par exemple :

- Élaborer un produit qui utilise l'information statique du SIA pour déterminer si un navire devrait également émettre pour le système LRIT.

- Élaborer un produit qui déclenche une recherche dans la base de données concernant un navire qui émet uniquement pour le système LRIT dans une zone couverte par des récepteurs du SIA, afin de déterminer si le navire respecte les règles d'émission du SIA.
- Élaborer un produit qui génère une carte à toutes les 6 heures ou qui indique la dernière position connue de tous les navires ayant omis de produire un rapport de position prévu pour le LRIT.

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Acknowledgements

Thanks to the Canadian Coast Guard for providing the author with the LRIT data used in this study.

Special thanks to Andrew Szeto of the Canadian Coast Guard for answering all questions pertaining to LRIT.

Notice to Readers

It should be noted that at the time of this study, Canada's LRIT system was in its infancy and not fully operational. Any further use of the LRIT analysis performed in this document as a basis and/or benchmark for any future studies related to LRIT is not endorsed by the Canadian Coast Guard.

1 Introduction

The 1974 International Convention for the Safety of Life at Sea (SOLAS) is an international treaty. The international shipping community recognizes it as the overarching document, which covers many safety related topics. Minimum standards for the construction, equipment and operation of ships, as they pertain to safety, are specified in the SOLAS. Flag States (e.g., countries) are responsible for ensuring that ships under their flag comply with SOLAS requirements. The International Maritime Organization (IMO) is the body that maintains the 1974 SOLAS Convention.

The 1974 SOLAS Convention has been amended repeatedly since it was adopted, to keep it current. The amendments to the 1974 SOLAS Convention are put forward by the IMO. One amendment was concerned with automatic identification systems. The system that satisfied this requirement came to be known as the Automatic Identification System (AIS). Another amendment was concerned with long-range identification and tracking of ships. The system that satisfied this requirement came to be known as the Long-Range Identification and Tracking system (LRIT). The IMO is the authority on both AIS and LRIT.

AIS was originally designed for collision avoidance with the goal of ensuring safe navigation. LRIT was designed for maritime security. LRIT was planned to provide global identification and tracking of ships for the purpose of state security, while AIS was originally planned to provide a ship or shore based receivers with a local picture of ship traffic to help ensure safe navigation. Both systems can be utilized for activities such as Search and Rescue, environmental protection and monitoring shipping activities.

The AIS and LRIT systems that emerged from these two amendments have certain similarities. One of the fundamental similarities is that vessel information is transmitted automatically within both systems. They are both self-reporting systems. In addition, while AIS and LRIT have different purposes, within those purposes they actually provide similar information. A fundamental difference between the systems is that AIS was designed to transmit ship to ship and ship to coastal authority, meaning anyone with an AIS receiver can pick up the transmissions. LRIT was designed to transmit from ship ultimately to governments with a need to know, meaning ships only transmit LRIT information, they do not receive it. This fundamental difference has resulted in the fact that AIS data are readily available to anyone with an AIS receiver or an internet connection while LRIT data are only available to government departments with a need to know. AIS data and systems are therefore more commonly reported on in the open literature than the LRIT data/system because of this fundamental difference.

One goal of this report is a closer examination of LRIT data to better understand it. It should be noted that only a month worth of data were used in this examination and the data were collected during the development stage of the implementation. The analysis itself was conducted in 2011. In 2010 not all LRIT Data Centres had been established. The LRIT system is dependent on all SOLAS Contract Governments to have established a Data Centre in order to transmit and receive vessel position reports, and in 2010 this had not yet been achieved. As of 2014, over 100 SOLAS Contacting Governments had established their National Data Centre and/or have plugged into a Regional/Co-operative Data Centre for the purpose of making the international LRIT system more robust than when this study was conducted The analysis here does not look at modern

instantiation of the system; therefore, observations should not be taken to represent the modern system The subsequent goals of this report are to examine how AIS and LRIT information complement each other and how combining AIS and LRIT information can improve maritime situational awareness.

1.1 Introduction to LRIT

In January 2008, an amendment to Chapter V (Safety of Navigation) of the 1974 International Convention for the Safety of Life at Sea came into effect that pertained to long-range identification and tracking, later known as LRIT. LRIT, as outlined in Regulation 19-1 [1], concerns mandatory position reporting for SOLAS class ships. The Chapter V Regulation 19-1 requires the automatic transmission of certain information (numbers refer to paragraphs):

1. 5.1 the identity of the ship;

2. 5.2 the position of the ship (latitude and longitude); and

3. 5.3 the date and time of the position provided [1].

Further ship identifiers (e.g., ship identification numbers, ship name), other time stamps, and the LRIT data centre identifier are added elsewhere as the data travels through the LRIT system network (Table 2 in Resolution MSC.263(84) [2]). The essence of the LRIT system is that participating countries get information, at least every 6 hours, on their own-flagged SOLAS class ships wherever they are in the world and on certain foreign-flagged SOLAS class ships. The rules and regulations are further discussed in Section 1.3, but for further details not covered here, see Long Range Identification and Tracking: Guide to Requirements and Implementation [3] put out by the Australian Government for an easily read document on the topic, as well as MSC.202(81) [1] and MSC.263(84) [2] for precise details.

In Canada, the Canadian Coast Guard (CCG) is responsible for the operationalization of LRIT [4]. Polestar, Canada's LRIT service provider is responsible for the Canadian LRIT National Data Centre (NDC) and its maintenance. The NDC's responsibilities include collection, dissemination and management of all LRIT information from Canadian-flagged SOLAS class vessels and the collection of foreign-flagged vessel LRIT information from other Data Centres. Transport Canada is responsible for encouraging the regulation is met by Canadian-flagged ships. The LRIT data analysed in this document were provided by CCG. One of the goals of this document is to better understand the LRIT data source.

1.2 Introduction to AIS

In 2000, a revision to Chapter V of the 1974 International Convention for the Safety of Life at Sea was adopted, which came into effect July 1, 2002. It pertained to automatic identification systems, later known as AISs, that would automatically provide ship information to other ships and coastal authorities in the area, as outlined in Regulation 19.2 (revised SOLAS Chapter V [5]). Its primary purpose is to assist in collision avoidance. It also allows maritime authorities to keep abreast of ship movements. The essence of AIS is that participating ships and coastal authorities receive information from other participating ships that are within reception range. All ships

affected were required to adhere to the regulation by the end of 2004 [6]. Some countries have increased the types of vessels that are required to participate in AIS within their waters. These are not discussed here.

There are 27 different AIS message types [7]. The information transmitted in an AIS message varies depending on the message type. It can include, but it is not limited to, ship identifiers, ship type, ship position, destination, cargo time, etc. The rate at which AIS messages are broadcast depends on the speed of the vessel and the type of AIS broadcasting the message (e.g., Class A shipborne mobile equipment, Class B shipborne mobile equipment, AIS base station, etc.). The intervals between broadcasts can vary from 2 seconds to 3 minutes. For more specific details, see the "Technical characteristics for an automatic identification system using time-division multiple access in the VHF maritime mobile band" (http://www.itu.int/rec/R-REC-M.1371-4-201004-I/en) [7].

The output of AIS is not government centric, unlike LRIT. In Canada, the Canadian Coast Guard has built and is responsible for a network of shore-based AIS base stations that can monitor ships within 40 to 50 nautical miles off the coast. This is part of the national AIS network.

In addition to land based receivers, AIS transmissions can also be received on Earth orbiting platforms, such as satellites and the International Space Station. This is often referred to as space-based AIS or S-AIS. This provides an opportunity for receiving AIS messages from vessels in open water and remote locations, similar to LRIT. Although this mechanism allows for improved spatial coverage over land-based receivers, at this time the orbits of the satellites give only periodic temporal coverage. In addition, there are complications related to interference between AIS messages from multiple ships that arise when using AIS receivers on satellites. Note that space-based AIS data is not used in this document.

Since AIS has been around several years longer than LRIT, and AIS information is readily accessible to anyone who wants it, much more study has been done on the topic of AIS. AIS related studies have examined, for example, AIS reception characteristics [8]; the use of AIS in vessel traffic services [9]; the use of AIS receptions from space platforms [10]; the combination of AIS and HF surface wave radar for monitoring the coastline [11]; and the problems using AIS could cause [12]. The existing research on AIS allows this report to focus more on LRIT.

1.3 Report outline

This report is structured as follows: Section 2 starts out with a discussion of the differences and similarities between LRIT and AIS, followed by a description of the data used in the analysis. This is followed by a record of the observations made concerning LRIT information and when LRIT data were combined with AIS data. Subsections 2.4 and 2.5 examine the geographic extent of the LRIT data and anomalies found in the LRIT information, respectively. Subsection 2.6 examines AIS and LRIT data together for the same time period. The final subsection examines LRIT from a maritime situational awareness point of view. Much of the analysis was accomplished using a combination of IDL, Excel and Google Earth. In Section 3, concluding remarks are made.

2 Analysis

2.1 What are the differences & similarities between LRIT and AIS?

As self-reporting systems, LRIT and AIS have many differences. AIS is meant to be used to avoid ship collisions while LRIT is used to monitor certain ships of interest to the state (e.g., own ships abroad and foreign vessels approaching or in the state's waters). These fundamental differences influence both the way the self-reporting systems are designed to work and how often the self-reports are required. For example, for collision avoidance, only vessels in the immediate vicinity need to know a ship's position; therefore, ship to ship VHF transponders are adequate. For LRIT, the global nature of the system appears to have driven the need for adopting a satellite based system for LRIT report transmission. In addition, to help prevent ship collisions, AIS sends reports at a rate that is appropriate to the speed of the vessel, while for LRIT, reporting every 6 hours was deemed adequate to track of ships of interest to the state. LRIT's purpose is based in helping a state build Maritime Situation Awareness (MSA). AIS is also useful in helping build MSA, though this is limited by the coverage of the AIS receiver(s) being used. Using both types of data to help achieve MSA is explored in this report.

To better combine and use the data from these two sources, the differences in reporting rules must be understood. To begin, Table 1 summarizes which vessels are mandated to broadcast AIS and which vessels are mandated to transmit LRIT information.

Table 1: The vessels mandated to broadcast AIS and transmit LRIT information.

AIS **(http://www.imo.org/ourwork/safety/navigation/pages/ais.aspx)[6]**	**LRIT** **(http://www.imo.org/OurWork/Safety/Navigation/Documents/LRIT/MSC.202(81).pdf)[1]**
all ships of 300 gross tonnage and upwards engaged on international voyages	cargo ships, including high-speed craft, of 300 gross tonnage and upwards on international voyages
cargo ships of 500 gross tonnage and upwards not engaged on international voyages	
all passenger ships irrespective of size	passenger ships, including high-speed passenger craft on international voyages
	mobile offshore drilling units on international voyages

The reporting requirements overlap for:

- Cargo ships over 300 gross tonnage on international voyages will be broadcasting both AIS and LRIT.
- Passenger ships on international voyages will be broadcasting both AIS and LRIT.

In other cases the reporting requirements do not overlap. In the following AIS reporting is required while LRIT is not:

- Ships over 300 gross tonnage on international voyages but not classified as cargo ships will broadcast AIS but not LRIT.
- Cargo ships over 500 gross tonnage not on international voyages will broadcast AIS but not LRIT.
- Passenger ships not on international voyages will broadcast AIS but not LRIT.
- Ships adhering to their own country's supplemental AIS broadcasting regulations or simply have an AIS transponder but do not legally need one would likely be broadcasting AIS but not LRIT.
- If a vessel is fitted with an AIS and operates exclusively within sea area A1, as defined in regulation IV/2.1.12, it will only have to broadcast AIS not LRIT.

In one case, LRIT reporting is required while AIS is not:

- Mobile offshore drilling units considered on international voyages are mandated to be broadcasting LRIT but not AIS.

In addition to the criteria that determine if a ship has to broadcast LRIT, Sections 7 and 9.1 of Regulation 19-1 of the SOLAS Chapter V Safety of Navigation [1] discuss situations when LRIT broadcasts can be curtailed or not distributed. In both cases, it suggests that if the safety, security or other concerns of the vessel (or vessels) is in question, the vessel(s) can either stop broadcasting (Section 7) or its flag's administration can request that the LRIT information not be forwarded to the Contracting Governments[1] whose 1000 nautical mile limit the vessel(s) is passing through (Section 9.1). Its AIS may or may not be broadcasting.

The general observation from these transmitting overlaps and lack of overlaps is that if a vessel is broadcasting LRIT it likely is also broadcasting AIS, but the reverse is not true. The fact that there are many circumstances above where a ship might be broadcasting only AIS, not LRIT, seems to point towards AIS being more useful than LRIT in building MSA, from the increased number of vessels broadcasting it. However, it should be remembered that the use of VHF to broadcast the AIS messages will limit reception of AIS messages to those within range of a state's receive stations or receive stations the state is buying data from (such as on a satellite). The LRIT system, on the other hand, gives global coverage to all states participating.

So far, the rules for transmitting AIS and LRIT have been discussed. Receiving either AIS or LRIT position reports have their own constraints. As mentioned, AIS messages will only be

[1] Contracting Government is the name for any government of a nation that is a signatory to SOLAS.

received if there is a receiver within range. Receivers can be nearly anywhere: ship based, land based, air based, satellite based, etc.

Barring exceptions, such as the ones already mentioned above, a Contracting Government has the right to receive LRIT position reports for security and other purposes as agreed by the IMO under certain defined circumstances. The Contracting Government has the right to receive LRIT position reports:

- for all ships entitled to fly the flag of the Contracting Government no matter where the ships are located. (Resolution MSC.202(81) 8.1.1)[1];
- if a ship has indicated to the Contracting Government their plan to enter a port facility of the country of said Contracting Government or to enter a place under jurisdiction of said Contracting Government. The exception to this rule is when the ship is "located within the waters landward of the baselines, established in accordance with international law, of another Contracting government"; e.g., if a ship is docked in Seattle, but has notified Canada of its intent to dock at a Canadian port, Canada will not receive LRIT information from the vessel until it is out of the American inland waters. (Resolution MSC.202(81) 8.1.2)[1]; and
- if a ship of another Contracting government is navigating within the 1000 nautical mile limit of the Contracting Government. Like above, the exception to this rule is when the ship is "located within the waters landward of the baselines, established in accordance with international law, of another Contracting government". Another exception to this rule is that the Contracting Government is not entitled to LRIT reports if a ship is within the territorial sea of another Contracting Government whose flag it is entitled to fly. (Resolution MSC.202(81) 8.1.3)[1].

The Contracting Government does not have the right to receive LRIT information from a vessel in the territorial sea of the Contracting Government whose flag the vessel flies (Resolution MSC.202(81) 8.1.4)[1]. It appears, in practice, the Canadian NDC also has the authority to start receiving LRIT information on foreign vessels that are destined for Canadian ports after they've submitted a Notice of Arrival, which is typically 96 hours prior to arrival and up to 2,000 nautical miles off of the Canadian coast [13].

2.2 The Datasets

The LRIT data used in this report were obtained from the Canadian Coast Guard (CCG) and consist of data obtained by the CCG from the LRIT system during the month of October 2010. The AIS data used were obtained from the Maritime Safety & Security Information System (MSSIS) [14], an international data aggregation and distribution system for close-to-real-time AIS data. The MSSIS data were amassed for a predefined rectangular area, shown in Figure 1, with an upper left corner of 132°W longitude and 52°N latitude and a lower right corner 121.0869°W longitude and 47.0104°N latitude. The bounding area was chosen based on observed boundaries for AIS reception to the north and west. There is very little known about the AIS data being provided by MSSIS in this area; for example, who is providing the data, the position of the AIS receivers and whether the data are being decimated/altered before being given to MSSIS are unknown. We do know that MSSIS does decimate the data for bandwidth reasons. The data collected spanned all of October 2010.

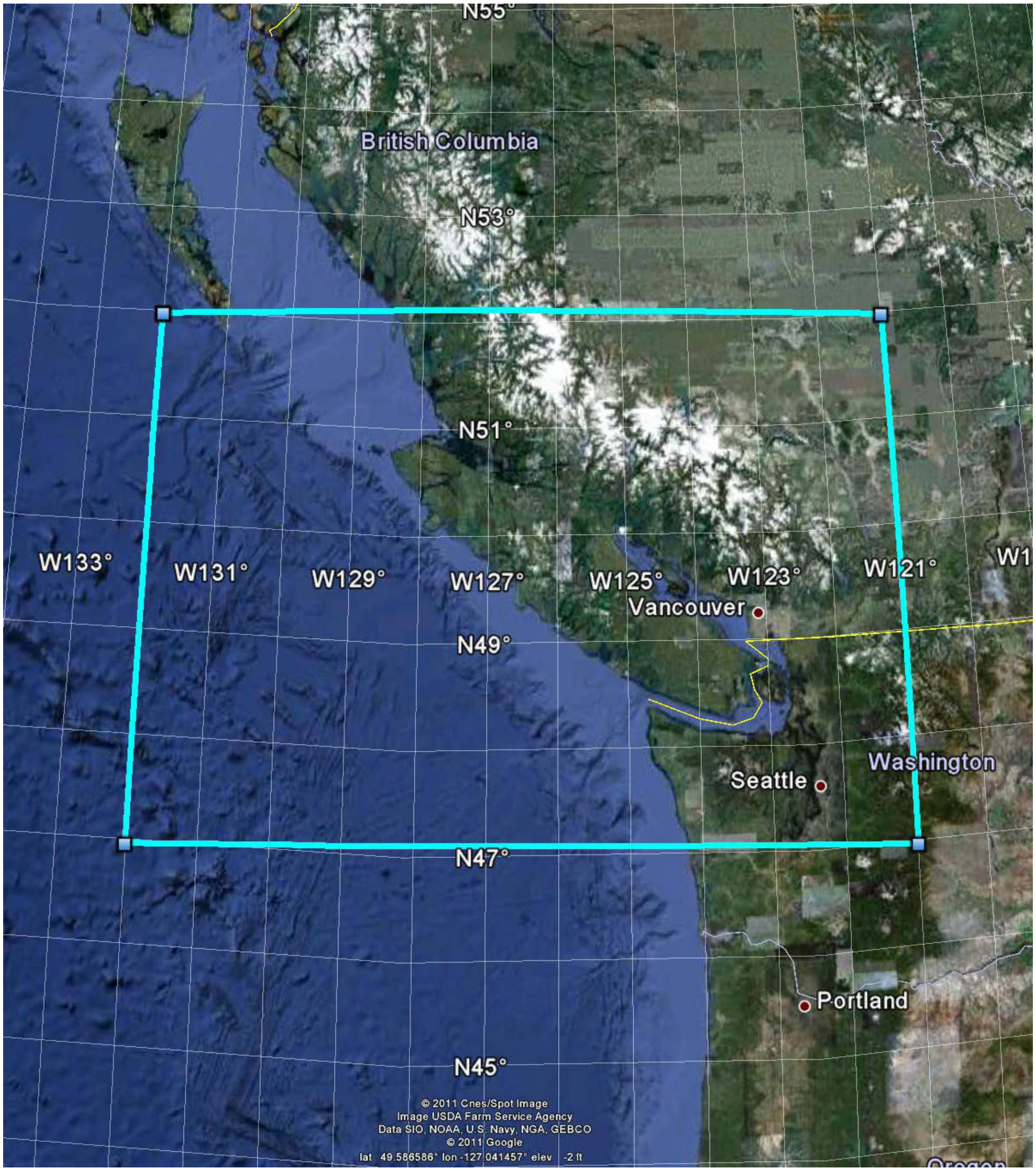

Figure 1: AIS collection area. (The bounding area, unlike the box drawn, followed the lines of latitude.)

The immediate difference noticed between the two datasets was the volume of data. The AIS data totalled 1.17 GB of parsed data (only date, time, Maritime Mobile Service Identity (MMSI) number and position were kept) that were saved in plain text (.txt) files. The LRIT data was provided in a 47 MB comma separated variable format file with 18 fields for each LRIT report. The LRIT data provided had every report CCG had received from anywhere in the world during October 2010. The AIS data was limited to the bounding box and was decimated by MSSIS and

may have been decimated by the original providers of the data. Despite these caveats, it is easy to understand the difference in data (file) sizes given the nature of each data source.

2.3 General observations about the LRIT dataset

For those unfamiliar with LRIT data, here are some general observations made about the dataset containing all the LRIT data that Canada received during October 2010.

Table 2: General observations made regarding the LRIT data set. Some characters have been blanked out to preserve the privacy of the vessel or coast station.

Aspect	Observation
Number or LRIT position reports	83677
Number of LRIT position reports time stamped within October 2010 (Zulu)	83666
Number of LRIT position reports where the first time stamp has a non-zero value for the seconds	1304
Number of unique IMO numbers (i.e., unique vessels)	2697
Sample: The first three IMO numbers (numerically)	3, 10002[redacted]9, 10054[redacted]1
The number of unique ship names	2696
Sample: The first three unique ship names (alphabetically)	[blank], ???, AC[redacted]D
The number of unique MMSI Numbers	2703
Sample: The first three unique MMSI Numbers (numerically)	-2147483648, 88208[redacted]2, 353487[redacted]1
MMSI numbers not associated with a country (ignoring the negative MMSI number)	458822000, 639090883
The number of unique Shipborne Equipment Identification numbers	2509
The number of unique LRIT position report Types	3
The three unique position report Type Names are	Periodic position report, Polled position report, SAR position report

The number of unique Data Centre Identification numbers & Data Centre Names	32
The number of unique Provider Identification numbers & Provider Names	51

2.3.1 Vessel identifiers

Examining Table 2, the number of unique IMO numbers, unique ship names and unique MMSI numbers are all different. The number of IMO numbers and unique ship names should be close to being equal, which they are; however, the number of MMSI numbers will likely be different given their nature. The observations concerning the ship identifiers are consistent with what is expected.

In regards to the actual identifiers, note how in Table 2:

- one IMO number was a “3”,
- there were ship names left blank, and
- there were at least two fake MMSI numbers.

Such anomalies might be cues for an operator to further investigate the vessel or query who is responsible for adding that incorrect information to the LRIT information. Delving deeper into these anomalies:

- The vessel with the IMO number 3 also had text (rather than a number) as its MMSI number that caused the value to be represented as a negative number in the analysis, and
- The vessel with “???” as its name, had a name in Asian characters in the original data file, that should have been changed to English using the latin-1 alphabet and UTF-8 encoding at some point, according to Resolution MSC.263(84) Table 2 [2].

According to Resolution MSC.263(84) Table 2 [2], it is the Application Service Provider (if used) that adds the IMO, MMSI and ship name to the LRIT information originally transmitted, which begs the question why is it adding obviously incorrect information?

On a side note: The nature of MMSI is that the number does not always refer to a vessel. MMSI numbers are categorized as:

- ship station identities (9 digits),
- group ship station call identities (8 digits plus a leading zero),
- Coast station identities (7 digits plus two leading zeros), and
- Group coast station call identities (7 digits plus two leading zeros).

If the MMSI has 9 digits with no leading zeros it is a single ship. In our analysis using MMSI numbers later in this paper, we limit the analysis to using LRIT reports and AIS messages that have nine digit MMSI numbers with no leading zeros.

2.3.2 Time Stamps

A further observation from Table 2 is that less than 2% of LRIT reports have time stamps with non-zero second values. This suggests that either the onboard LRIT reporting system generally transmits exactly on the 0^{th} second or that most time stamping is only accurate to the minute. Whether time stamps are accurate to the second or the minute has implications when un-decimated AIS data is combined with LRIT data. AIS messages can be broadcast every 2 seconds under certain circumstances, which suggest there could be 60 AIS messages within +/- 1 minute of the LRIT timestamp, if it is only accurate to the minute.

2.3.3 LRIT itself

It was observed that LRIT has been set up in ways that are subtly different than those recommended in the resolutions that were reviewed. According to Resolution MSC.263(84) Table 1 [2], it is the shipborne equipment identifier that is transmitted by the ship as part of the LRIT information, along with the position data and initial time stamp. Resolution MSC.202(81) Chapter V Regulation 19-1.5 [1] states that ships shall automatically transmit “the identity of the ship” along with its position and date and time of the position. Note that the number of unique Shipborne Equipment Identification Numbers in the dataset is considerably less than the number of unique IMO numbers, MMSI numbers, and ship names, suggesting this cannot be used as a vessel identifier, which is implied by combining the two resolution statements above. Upon further examination of the data, many Shipborne Equipment Identification Numbers are assigned to be zero in the dataset. The comparatively low number of unique Shipborne Equipment Identification Numbers implies that another ship identifier must be broadcast by the equipment to identify the ship. It is clear that the LRIT information actually broadcasted must contain a more defining piece of metadata to distinguish the vessel.

Another way LRIT has been set up in ways that are subtly different than those recommended in the resolutions that were reviewed, is that the timestamps of the LRIT dataset are as follows: 1) sent from terminal, 2) received CSP (Communication Service Provider), 3) received at Application Service Provider (ASP) from CSP, and 4) received at Data Centre from ASP. The time stamps are a deviation from what was recommended in Resolution MSC.263(84) Table 2 [2]. Therefore, it appears that in practice, LRIT has been set up somewhat differently than suggested in the documentation.

2.4 The spatial extent of the LRIT data

2.4.1 Is there a noticeable limit to the data at the 1000 nautical mile boundary?

Canada’s NDC is allowed to receive LRIT reports for foreign vessels within its 1000 nautical mile limit that are not in inland waters of another country and for all Canadian vessels wherever they are in the world. In practice, the NDC also receives messages up to 2000 nautical miles off the Canadian coast after a vessel has given its Notice of Arrival. Therefore, it should be noticeable that most vessel reports start at the edge of the 1000 nautical mile limit with some starting beyond that limit. Indeed, that is the case when large amounts of LRIT data are plotted, as shown in Figure 2.

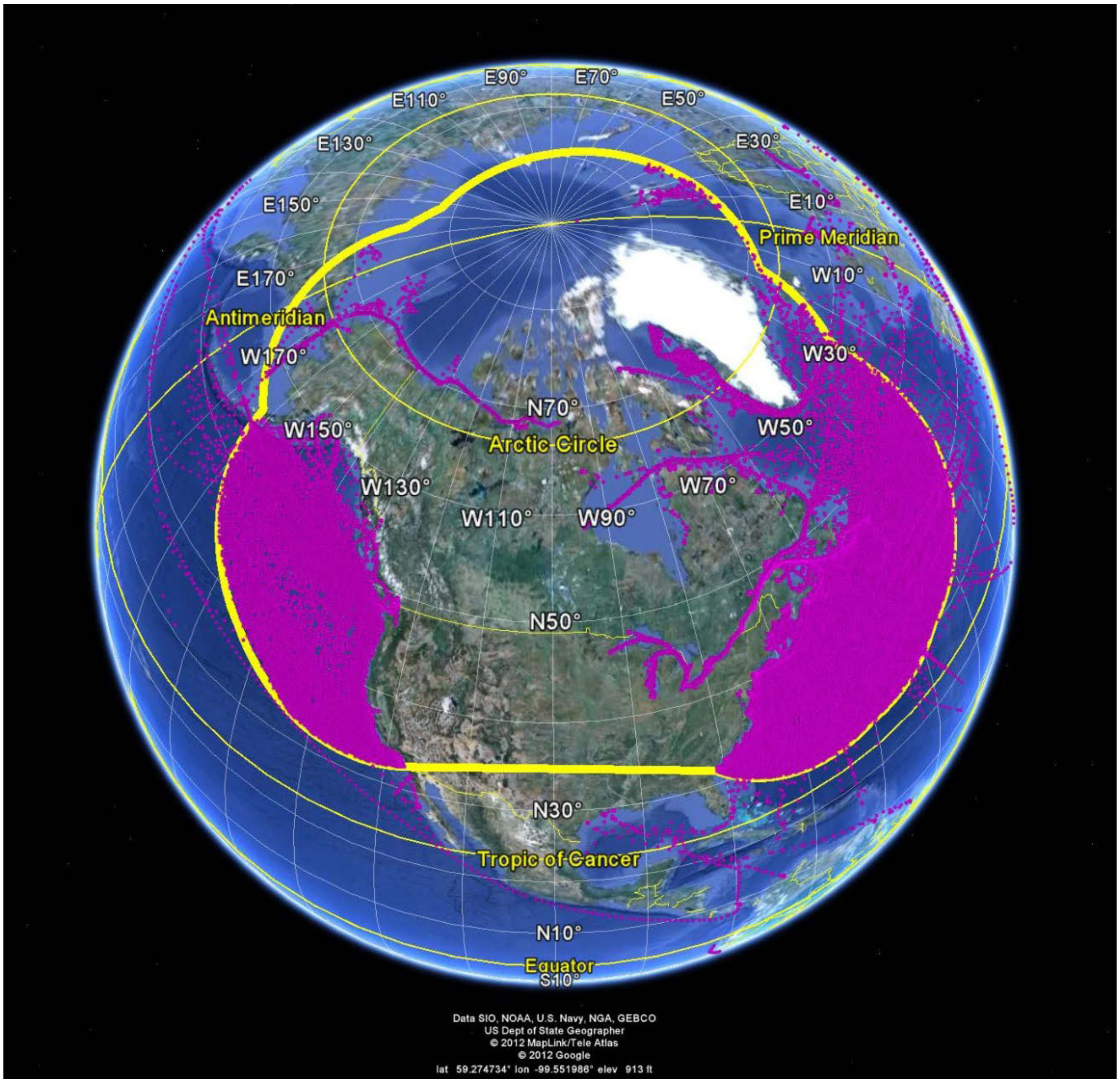

Figure 2: The positions in LRIT reports that Canada received in October 2010, with a focus on the 1000 nautical mile limit zone, which is outlined in a thick yellow line. Each LRIT position report is represented by a pink circle at the position listed in the report.

Figure 2 shows LRIT data that Canada received in October 2010, with a focus on the 1000 nautical mile limit zone, which is outlined in a thick yellow line[2]. Each LRIT position report is represented by a pink circle. Note that reports from the same vessel are not distinguished from reports from different vessels. As can be seen, the bulk of the reports are from within the 1000 nautical mile limit, while Canada received sparse reports outside the limits. (The reports outside the limits are discussed further in the next subsection.) The LRIT system appears to be working as intended in the sense that it is providing reports from within the 1000 nm limits but not within inland waters of the USA. The tracks, also, typically end/begin at the 1000 nautical mile boundary.

[2] The thick yellow line is the 1000 nm boundary, provided by the CCG and used in the LRIT system.

2.4.2 Is Canada receiving LRIT position reports beyond its 1000 nautical mile boundary?

Canada is receiving LRIT position reports beyond the 1000 nautical mile boundary, as can be seen in both Figure 2 and Figure 3. A random sampling suggests most reports are from foreign vessels. For example, Figure 3 shows the position of LRIT reports on October 19, 2010 in Indonesia. It's not obvious at this time why these data had been received.

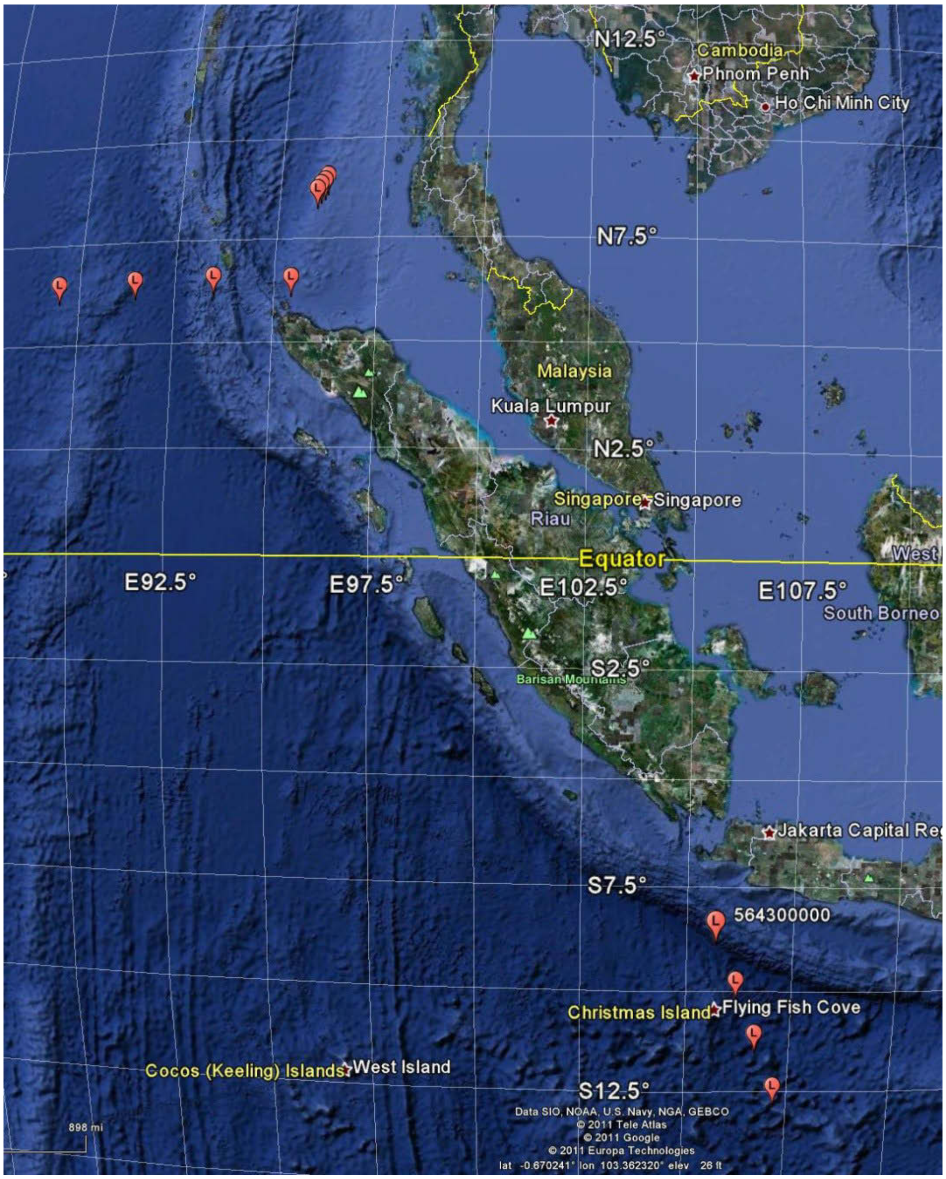

Figure 3: The positions of LRIT reports on October 19, 2010 in Indonesia. Red balloons with "L"s represent the location in the LRIT reports. None of these vessels are Canadian vessels.

2.4.3 Is there evidence of LRIT reporting vessels in the arctic?

Not all LRIT Communication Service Providers can receive LRIT reports from vessels in the arctic[3]. Yet one of the performance standards and functional requirements of LRIT is that "The shipborne equipment should transmit the LRIT information using a communication system which provides coverage in all areas where the ship operates" (MSC.263 (84) 4.3). Observing whether there is evidence of LRIT reporting vessels in the arctic is therefore actually observing whether there are vessels travelling within our 1000 nautical mile limit in the arctic that are using a Communication Service Provider that will allow them to report. Within the 1000 nautical mile limit, Canada did receive LRIT reports from north of the Arctic Circle, as seen in Figure 4, which plots positions of reports received by Canada for the entire month of October, 2010. In the figure, each LRIT report is represented by a pink circle at the position listed in the report. Reports from the same vessel and those from different vessels are not distinguished. There is one report very close to the North Pole, which is discussed in a later section. There is reason to believe that this is not an accurate position of that vessel. Ignoring that anomaly, the vessel report closest to the North Pole is at approximately 81° North. It is from a Norwegian vessel.

[3] For example, Iridium LRIT can receive reports in Sea Area A4, which includes waters above 70 degrees latitude. Using an Iridium terminal onboard the vessel would be required.

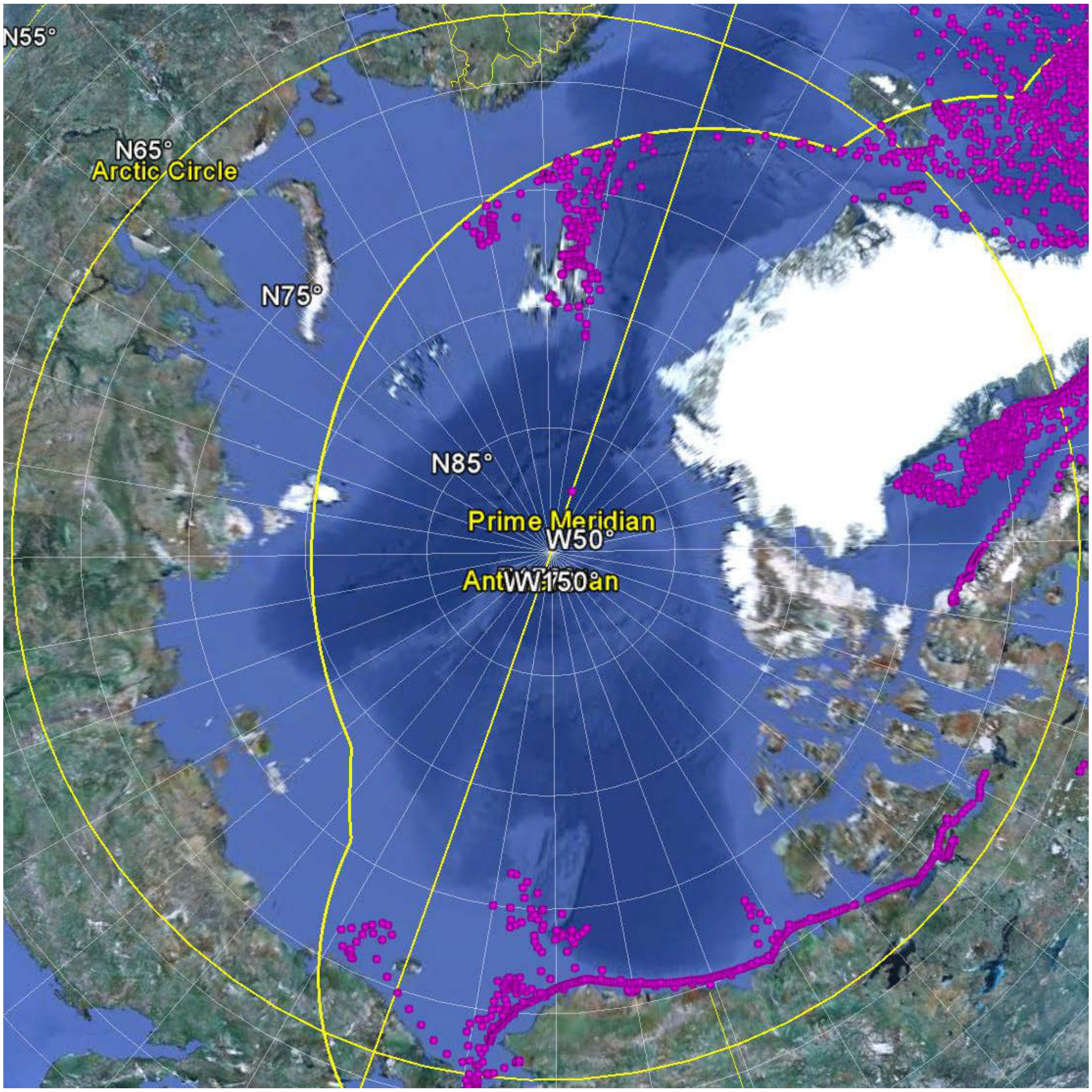

Figure 4: The positions in LRIT reports that Canada received in October 2010, with a focus on the Arctic Circle. Each LRIT position report is represented by a pink circle at the position listed in the report.

2.5 LRIT position reporting observations

To appreciate the discussion of LRIT position reporting tendencies, the following LRIT standards and functional requirements should be kept in mind (from Resolution MSC.263(84)) [2]:

4. Table 1: "*Pre-scheduled position reports*: The equipment should be capable of being remotely configured to transmit LRIT information at intervals ranging from a minimum of 15 min to periods of 6 h to the LRIT Data Centre, irrespective of where the ship is located and without human interaction on board the ship."

5. 4.4: "The shipborne equipment should be set to automatically transmit the ship's LRIT information at 6-hour intervals to the LRIT Data Centre identified by the Administration, unless the LRIT Data User requesting the provision of LRIT information specifies a more frequent transmission interval."

6. 4.4.1: "When a ship is undergoing repairs, modifications or conversions in dry-dock or in port or is laid up for a long period, the master or the Administration may reduce the frequency of the transmission LRIT information to one transmission every 24-hour period, or may temporarily stop the transmission of such information."

2.5.1 Vessels reporting LRIT information at more frequent intervals than every 6 hours

There are 83666 position reports that are time stamped in October 2010. There are 80969 pairs of reports where an interval can be calculated. There are 63745 pairs of reports that are time stamped exactly, to the second, 6 hours from the last position report, which is about 79% of the total intervals. It is found that ~20000 position reports were transmitted at either a shorter or longer interval than the default 6 hours. This discrepancy could happen due to the rules of LRIT (e.g., a vessel being asked to transmit more frequently would result in a shorter interval, a vessel leaving and then returning to the area within the 1000 nm limit would result in a longer interval, etc.), however, a simple data analysis suggests that LRIT rules are not always the cause.

Figure 5 shows a histogram of transmission intervals between 5 and 7 hours, using 60 second bins. Each bin is centered on the minute, e.g., bin 18900 s (= 315 minutes = 5 hours, 15 minutes) contains intervals that are greater than 18870 s and equal to or less than 18930 s. Since only 1304 reports (~1.6%) had non-zero seconds in their first timestamp, it can be assumed that most intervals will be at the bin label value. Note that the x-axis is logarithmic and therefore will not show zero or 1 value frequencies. Not including the end bins (which include all remaining data); there are 70061 intervals between 5 and 7 hours. Therefore, about 91% of the intervals that occur within 6 hours +/-1 hour are exactly 6 hours (63745 of 70061). There are 63924 intervals in this range that are in the 21600 s (or 6 hour) interval bin. Note that the number of intervals in the 6 hour bin and the number of intervals that are exactly 6 hours are different because of LRIT time stamps that have non-zero second values. The majority of LRIT transmissions within an hour of the default 6 hour transmission interval happen within +/-5.5 minutes of the 6 hour interval. Of the 70061 intervals, 69231 intervals (or 98.8% of intervals) fall within 6 hours +/- 2.5 minutes and 69490 (or 99.2%) fall within 6 hours +/-5.5 minute. That leaves 571 intervals in the figure that are not within 6 hours +/-5.5 minutes and not the end bins. The same analysis can be done for the 80969 pairs of reports where an interval can be calculated in the October dataset. Of the 80969 intervals time stamped in October 2010, ~85.5% had intervals within +/- 2.5 minutes of 6 hours. This statistic only goes up about 0.3% when it is increased to +/- 5.5 minutes.

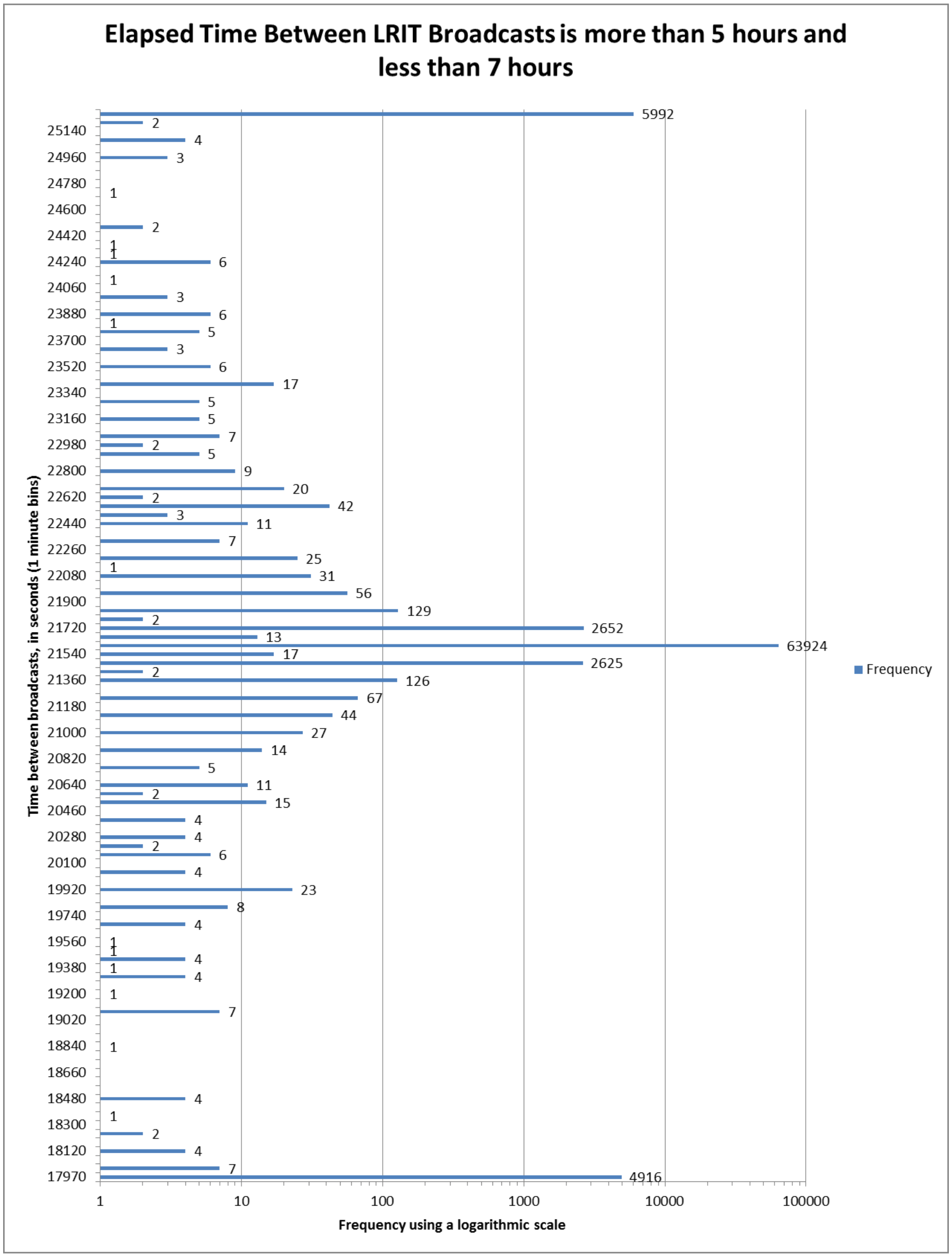

Figure 5: Elapsed time between LRIT broadcasts that are more than 5 hours but less than 7 hours. Note the logarithmic scale horizontally. The values on the vertical axis are the values at the middle of the bin; i.e., bin 18900 s contains intervals that are greater than 18870 s and equal to or less than 18930s. (18900 s = 315 minutes = 5 hours, 15 minutes.) All but 1.6% of time intervals are at the exact bin value.

Given that about 91% of the intervals that are between 5 and 7 hours are exactly 6 hours, one might conclude that all intervals not equal to 6 hours within this range are likely due either to inaccuracies in the onboard LRIT equipment, or due to the appropriate satellite not being within sight of the vessel, and therefore the report being stored until it can be transmitted. Certainly there could be some requests for transmissions during the 5 to 6 hour time period which would explain a non-6 hour time interval, but if the vessel will transmit at a 6 hour interval automatically, why make a slightly early request, especially if it could take up to half an hour (paragraph 13.2 [2]) for it to occur? In regards to transmissions between 6 and 7 hours, if the vessel left the 1000 nautical mile limit before the automatic 6 hour transmission and re-entered after the automatic 6 hour transmission, then the next transmission, from Canada's point of view, should have an interval at 12 hours. This is because the onboard transmission is not dependent on who is receiving the transmissions. As a result, such a scenario would not cause a transmission with a timestamp between 6 and 7 hours. However, if something is delaying the transmission, such as the satellite being out of range and the equipment saving the report and time stamping it when it is actually sent, this could explain transmissions between 6 and 7 hour intervals. In addition, if a previous transmission was delayed, but the next transmission was on time (i.e., 6 hours from when it should have been sent not when it actually was sent), then that could explain transmissions between 5 and 6 hour intervals as well. It is fair to say that the closer an interval is to 6 hours, the more likely the difference between it and 6 hours is a fault of the onboard LRIT system or something external to the system, not LRIT features or rules. Given that about 99% of transmissions in this time range were 6 hours +/-5.5 minutes apart, it is likely that the LRIT system is normally sufficiently timely for the LRIT data users. Investigations into the reasons for the untimely nature of the other 1% would likely help improve the system.

As stated, a contracting government participating in the LRIT system, such as Canada, can ask for a vessel to report more frequently than the default 6 hour reporting interval. Figure 6 shows the east coast of North America and plots the positions of pairs of transmissions that are less than 5 hours and 55 minutes apart. There are 8055 transmissions in the month of October that were transmitted at less than 6 hours after the ship's previous transmission (therefore, more than those shown). There are obvious tracks formed by vessels consistently reporting more often than every 6 hours. There are also instances where there are two LRIT position reports less than 6 hours apart without being in an obvious track. More investigation would be needed to determine if consistently reporting more often than every 6 hours is due to asking the vessels to report more often, an incorrect set-up of the LRIT system on board the vessel of those reporting (e.g., every hour), a flaw in the LRIT system, or an inexactness of the LRIT system.

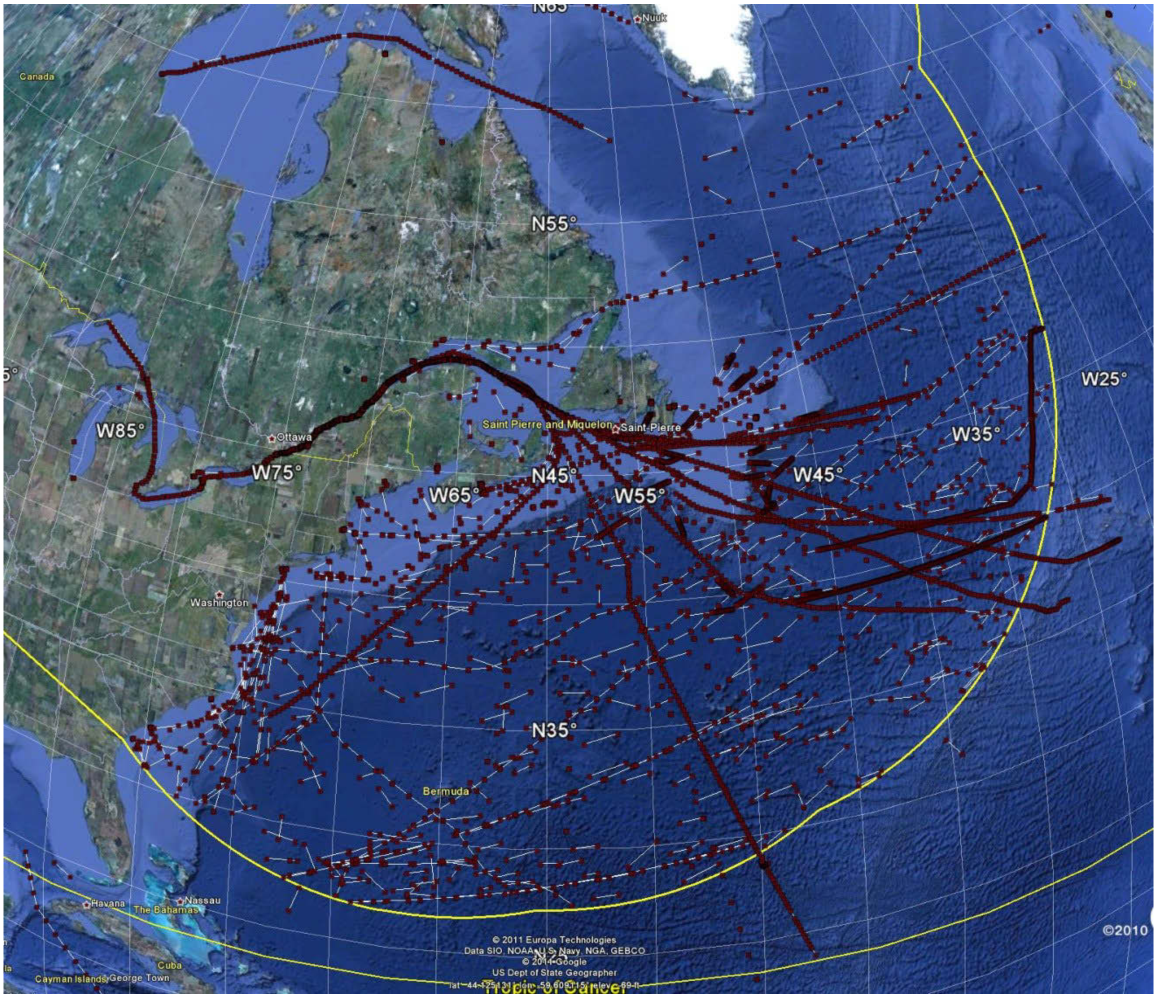

Figure 6: Pairs of LRIT reports that are less than 6 hours apart during October 2010, for the east coast of North America. Each time two position reports are less than 5 hours and 55 minutes apart a red mark is placed at the spatial location of both position reports and a white line drawn between them.

The histogram in Figure 7 focuses on LRIT transmissions with intervals less than 6 hours. Again, the bins are centered on the bin label, so the 21600 s or 6 hour bin, contains intervals greater than 5.5 hours and less than or equal to 6.5 hours. The most significant peaks, less than 6 hours, are at the 1 hour interval bin and the 0 hour interval bin. The long continuous tracks with dense position reports that can be picked out in Figure 6 are typically made from vessels reporting every hour. Multiple vessels reporting for a long period of time at a short interval would likely be the cause of the peaks at the low end of the histogram. In other words, a vessel consistently transmitting at one hour intervals would have more transmissions during the day than a vessel transmitting every 4 hours, thus skewing the histogram. Even given that fact, it still can be said that ships transmitting within the 5 hour (18000 s), 3 hour (10800 s) and 2 hour (7200 s) bins were not common.

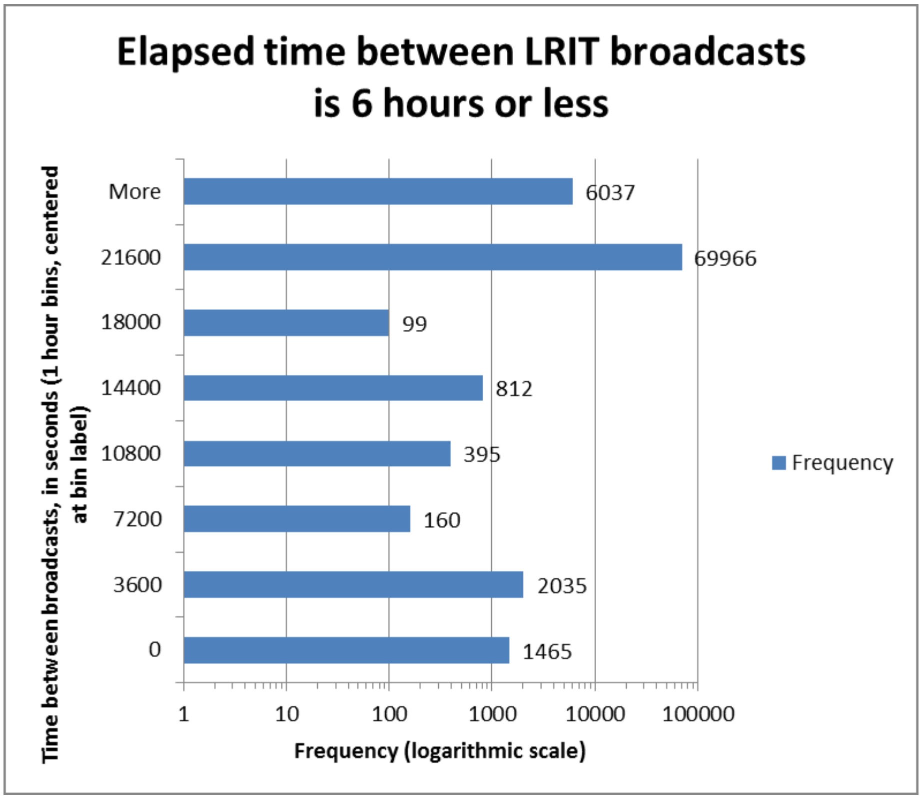

Figure 7: A histogram of LRIT transmissions with intervals less than 6 hours. Bins are centered on the bin label. The "More" bin includes all remaining data. Note that the horizontal axis is logarithmic.

2.5.2 Vessels reporting at greater than 6 hour intervals

While inside the 1000 nautical mile boundary, an LRIT transmitting vessel should be reporting at least every 6 hours if it meets the criteria mentioned earlier in this report, unless they or the flag state they belong to are invoking one of the exceptions. It is clear from the Figure 8 that this is not always the case. The figure covers all the month of October and plots the vessel positions of the two reports that were greater than 6 hours five minutes apart. Certain features can be explained. Canada will not receive position reports when a vessel enters US inland waters, which would explain the high density along the US coast. The white lines connecting the east and west coast of North America in the southern US are caused by vessels that made the trip between the east and west coast and left Canada's 1000 nm limit to do so.

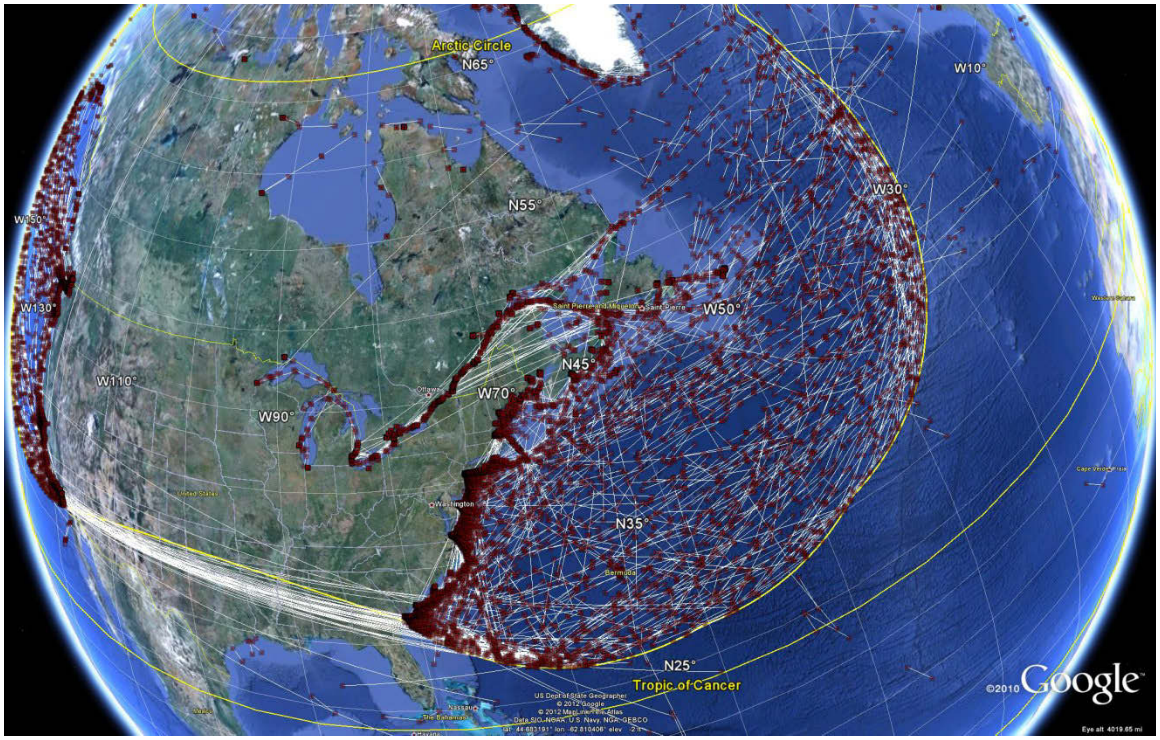

Figure 8: Pairs of LRIT reports that are more than 6 hours apart during October 2010, east coast of North America. Each time two position reports are more than 6 hours and 5 minutes apart a red mark is placed on the spatial location of both position reports and a white line drawn between them.

Individual ship tracks are hard to identify in Figure 8 but not completely absent. This is dissimilarity with Figure 6. Some vessels do form tracks of consistently large temporal gaps between reports. Figure 9 shows one such ship track. Canada received LRIT position reports from this vessel from October 4th to October 31st. Canada was regularly receiving LRIT transmissions that were time stamped at 03:07, 09:07, 15:07 and 21:07 each day until October 24th when Canada stopped receiving the 03:07 transmissions. The line is broken in the image because the other two transmissions were spaced 6 hours apart and therefore would not be shown. Whether the vessel stopped transmitting its 03:07 LRIT report or if Canada just happened to stop receiving them, is unknown.

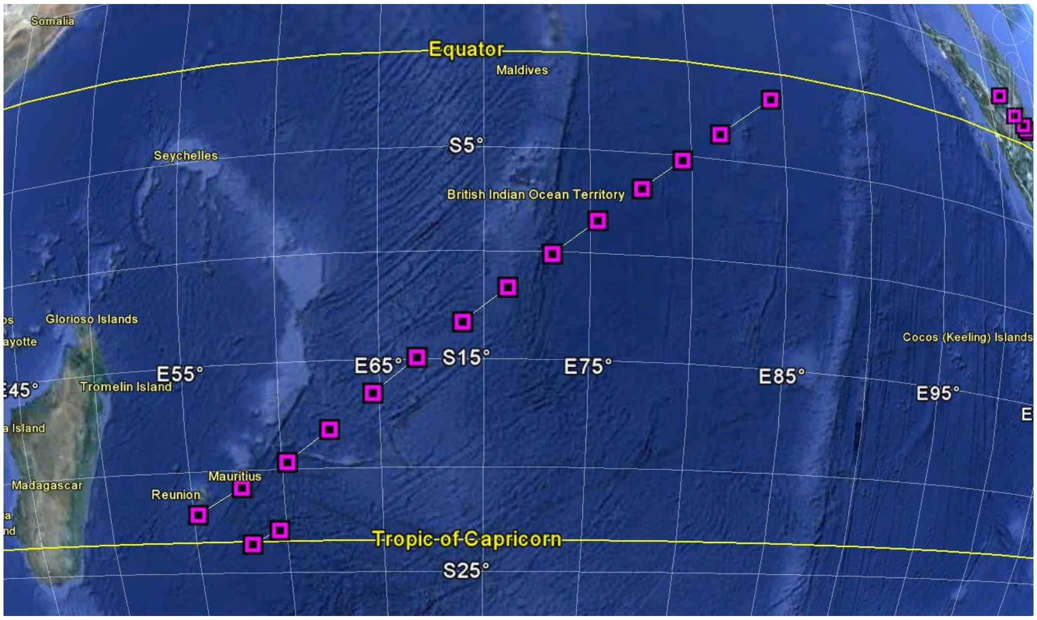

Figure 9: A foreign vessel for which Canada consistently missed one of its LRIT transmissions. From October 4th to 23rd Canada received all four daily transmissions. Starting October 24th the 03:07 report was not received for the remainder of the month.

2.5.2.1 Temporal Gaps in LRIT reporting

It is not unusual to find large (12 hours or greater) temporal gaps between LRIT pre-scheduled position reports. Known reasons for such gaps can be due to:

- rules that govern which LRIT reports Canada can receive (see discussion on LRIT intervals greater than 6 hours, Section 2.5.2), and
- exceptions to the rules that govern which LRIT reports Canada can receive, for example safety and security reasons, when LRIT pre-scheduled position reports will either not be made or will not be forwarded (Amendments to the international convention for the safety of life at sea, chapter V, regulation 19-1, paragraphs 7 and 9.1 [1]).

However, in addition to these legitimate reasons, gaps were observed in the dataset that perhaps were not legitimate. For example, it appears that pre-scheduled position reports can be missed both randomly and regularly, the latter shown previously in Figure 9. Regarding randomly missed reports, single reports can be missing as well as multiple days' worth of reports. For example, Figure 10 shows a 27 day gap between (assumingly) pre-scheduled position reports from a foreign vessel. There are two position reports Canada received outside the 1000 nm limit. Follow-on LRIT position reports then place the vessel in Lake Superior. After the initial large gap, position reports that are time stamped every 6 hours are received, with the exception of one that is time stamped 12 hours after the previous one. Only having the LRIT data, it is impossible to say if the gaps in LRIT pre-scheduled position reports were done on purpose under an LRIT regulation or were accidental.

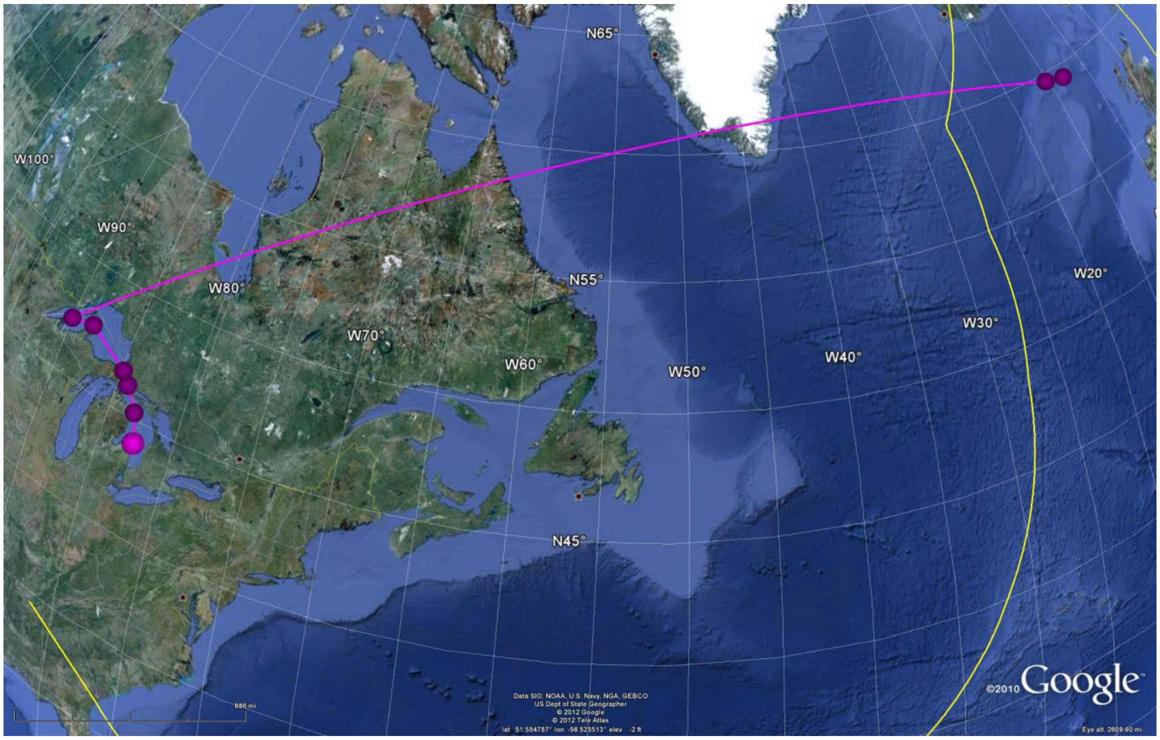

Figure 10: Pre-scheduled LRIT position reports for one foreign cargo vessel. The first two reports are from outside the 1000 nm limit. The third is 27 days later, in Lake Superior. After the initial large gap, there is an interval that is exactly 12 hours among intervals that are at exactly 6 hours.

Another example of a large temporal gap is seen in Figure 11. The top figure documents the LRIT pre-scheduled position reports as a foreign vessel travels to Delta, British Columbia. There is an 8 day gap in LRIT pre-scheduled position reports. After the 8 day gap, the vessel is in Delta. The second image shows the LRIT pre-scheduled position reports as the vessel leaves Canada. The vessel appears to take the same path, with no gap in LRIT information transmissions. This could suggest that it was not the waters the vessel travelled through that resulted in the stoppage of LRIT transmissions. If it was not intentional, something is not adhering to performance standards of the LRIT system.

A document submitted by the European Commission at the 10th Ad Hoc LRIT Group in September 2011 [15] did some statistical analysis on LRIT reports received by the European Union (EU) Cooperative LRIT Data Centre (CDC) from 2011-01-01 to 2011-06-30. They found the daily average of ships not reporting to the EU CDC is about 18%. They predicted that 77% of expected reports were received during the time of the study though this would be skewed high due to ships that are over reporting. Therefore, what was found in this study concerning temporal gaps between LRIT reports is in line with the European study.

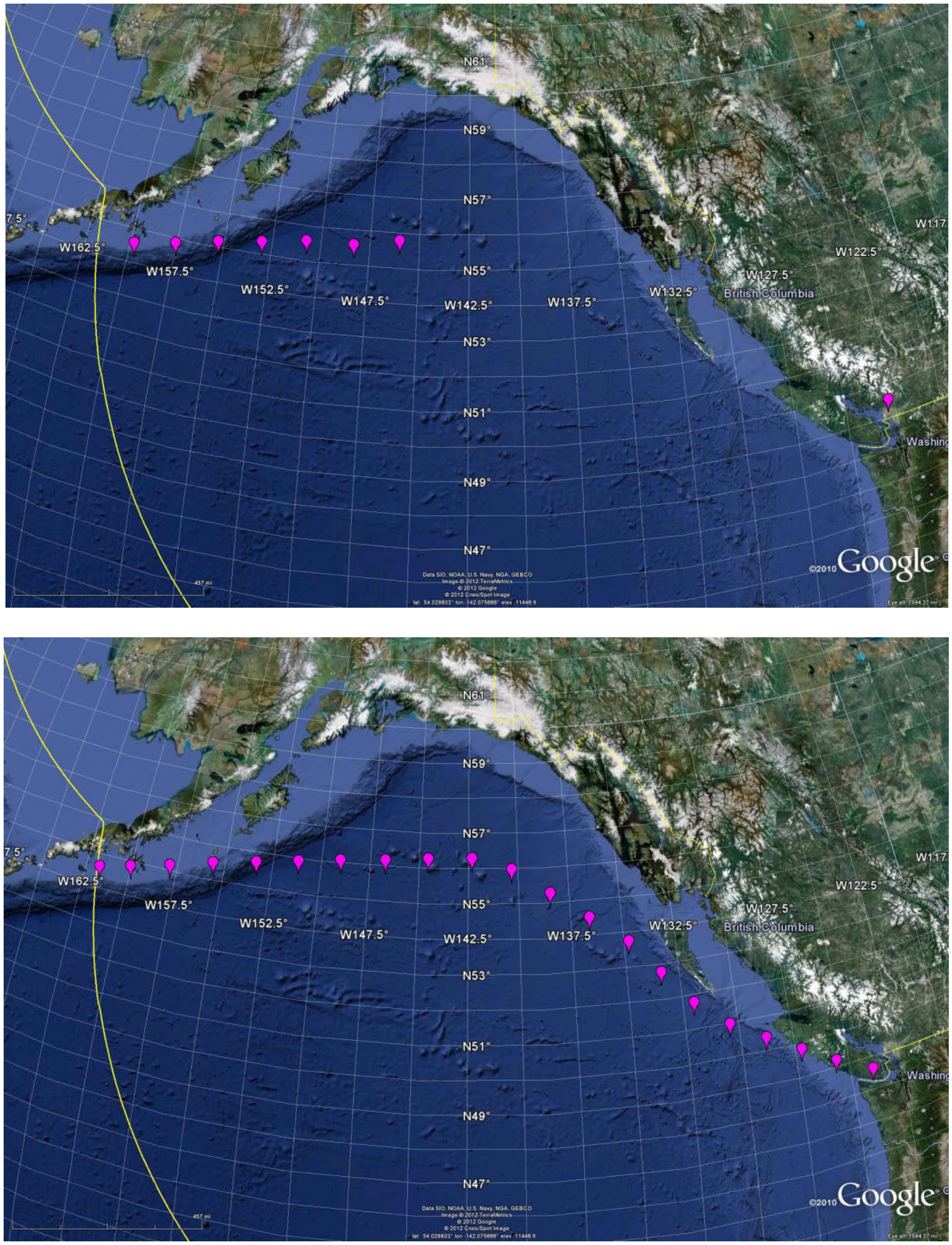

Figure 11: As a foreign cargo vessel travelled into Delta, British Columbia (top figure) there was a gap of 8 days (top figure) where no LRIT pre-scheduled position reports were received. The pre-scheduled position report ending the gap was in Delta. When leaving Canada (bottom figure), there was no gap in LRIT pre-scheduled position reports (bottom figure).

2.5.3 Vessels with position reports indicating unrealistic spatial separation

Some data in the LRIT reports have obvious errors. For example, a vessel claiming its IMO number is 3 or not including a vessel name, are cues that the vessel information is incorrect. Odd spatial characteristics can also lend cues. For example, see Figure 12. The very first LRIT position report in the dataset from this foreign vessel took place quite near the North Pole on October 28. The next position report on October 29th puts the vessel off the coast of California. After that, transmissions are either at a 6 hour interval, a 6 hours, 1 minute interval, or 6 hours, 15 minutes interval. Examining the series of LRIT position reports mapped by their reported positions leads to the assumption that the first pre-scheduled position report was wrong. Barring other barriers to transmitting the LRIT information on time and given that the first timestamp is from the shipbourne equipment, it is possible the equipment was not functioning properly based on the variety of time intervals between the transmissions. The default pre-scheduled transmission interval should be 6 hours.

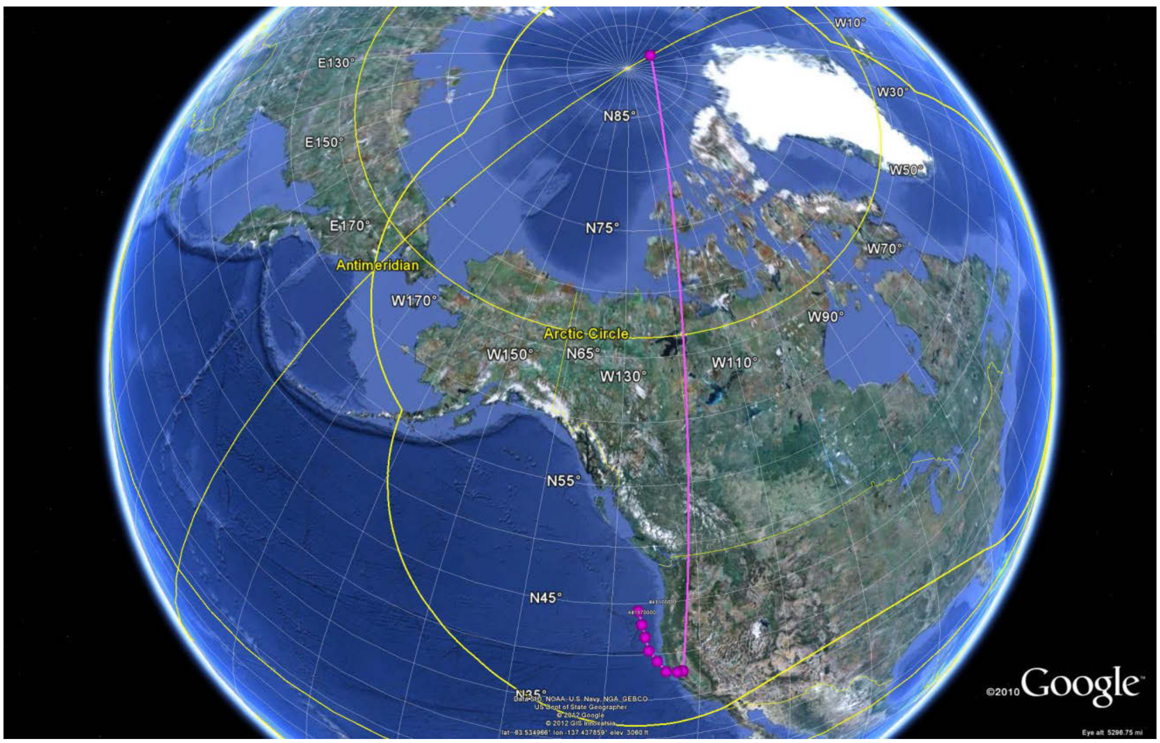

Figure 12: Anomalous position information. The first LRIT position report for this vessel on October 28 puts the vessel at the North Pole. Its next report on October 29th puts it off the coast of California. After the second transmission, reports are either at a 6 hour interval, a 6 hours, 1 minute interval, or a 6 hours, 15 minutes interval.

2.6 Superimposing LRIT data and AIS data

2.6.1 Do AIS data and LRIT data line up?

When mapping AIS transmissions and LRIT pre-scheduled position reports on the same map, a logical question is whether the AIS and LRIT reported positions match up when a vessel is transmitting both AIS and LRIT. As soon as LRIT and AIS transmitted positions are plotted for the same vessel, one of the most noticeable things is a spatial offset between the tracks. The following figures illustrate this.

The first image (Figure 13) shows positional data from a vessel that appears to be docked. Keep in mind the figure was created in Google Earth with an old satellite image in the background and does not represent the true situation. However, the AIS positions (i.e., the square symbols), are scattered tightly around a position near the dock and therefore a likely position for the vessel. The LRIT reports (i.e., the balloon) of which there are 7 overlapped, does not overlap with the cluster of AIS positions. All AIS and LRIT reports are from the same time period. The spatial offset is approximately 62 m from the approximate center of the AIS cluster to the LRIT reported positions.

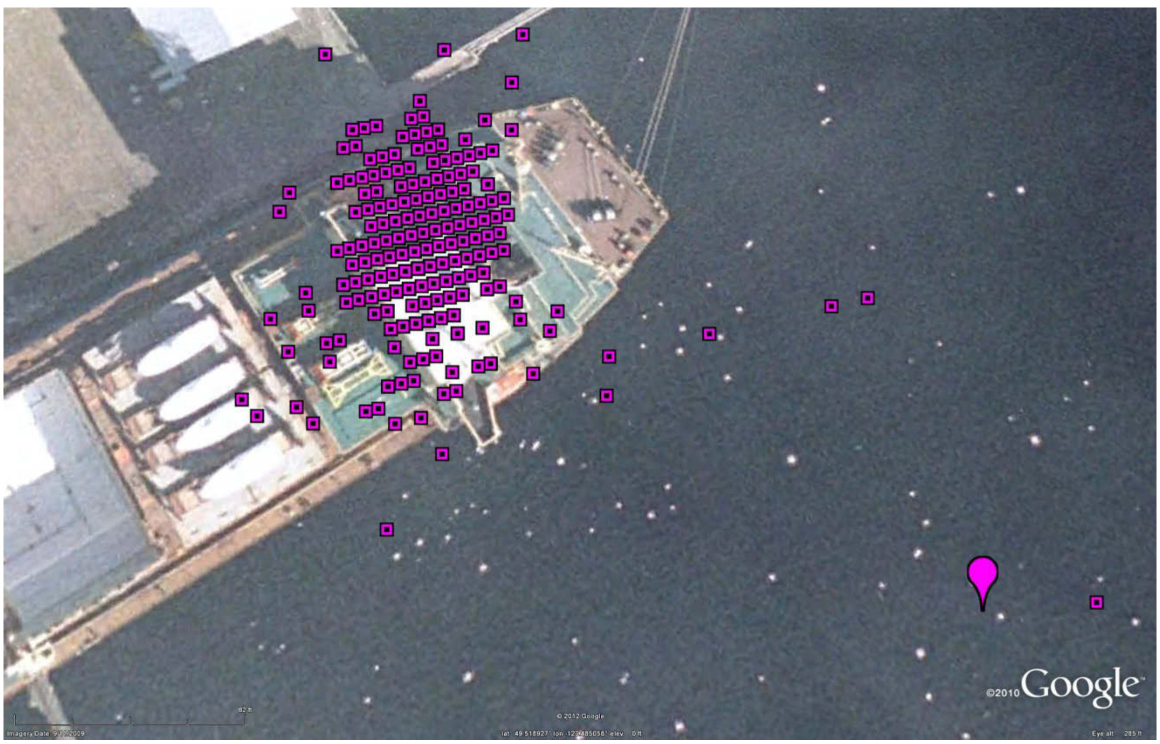

Figure 13: Both AIS and LRIT positional data from a vessel are plotted. The AIS positions are represented by pink squares (many unseen due to overlapping) while the 7 LRIT positions are represented by overlapping pink balloons. Note: The underlying image is a historical image from another date.

The next image (Figure 14) shows the same scenario for another vessel. In this case the 9 overlapped LRIT positions are on land. The offset is approximately 21 m from the center of the AIS cluster to the LRIT reported positions.

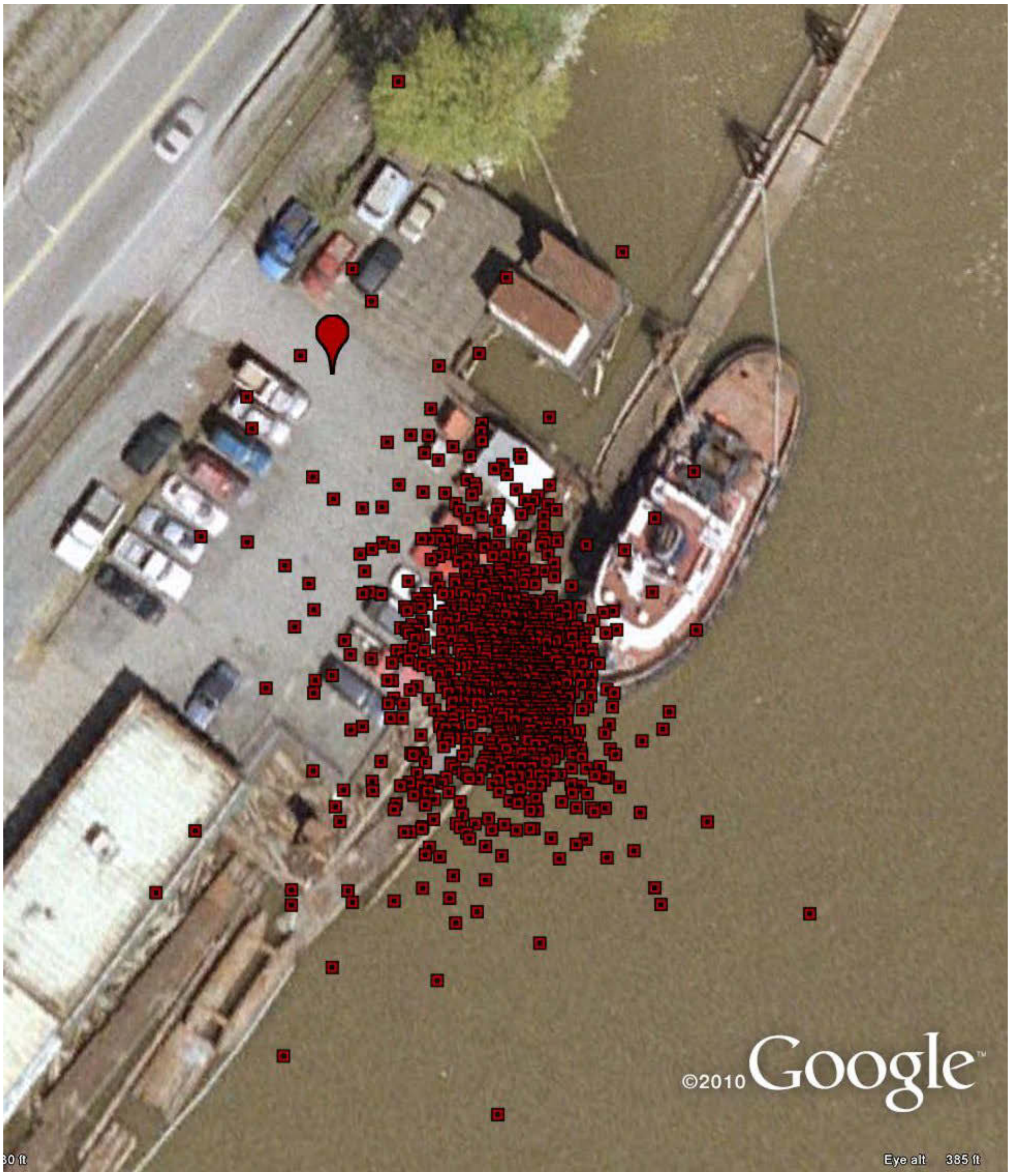

Figure 14: Positional data for a vessel from both AIS (red squares) and LRIT (9 overlapping red balloons). Note: The underlying image is a historical image from another date.

The next image (Figure 15) shows a ship that is likely anchored and drifting in circles. In this case, both the AIS and LRIT show somewhat circular patterns that are offset to each other. Note that for both LRIT and AIS there are reports that overlap geospatially with other LRIT and AIS reported positions and therefore there are more reports represented in the image than there

appears to be. The offset, from the approximate center of the AIS cluster to the approximate center of the LRIT cluster is roughly 281 m.

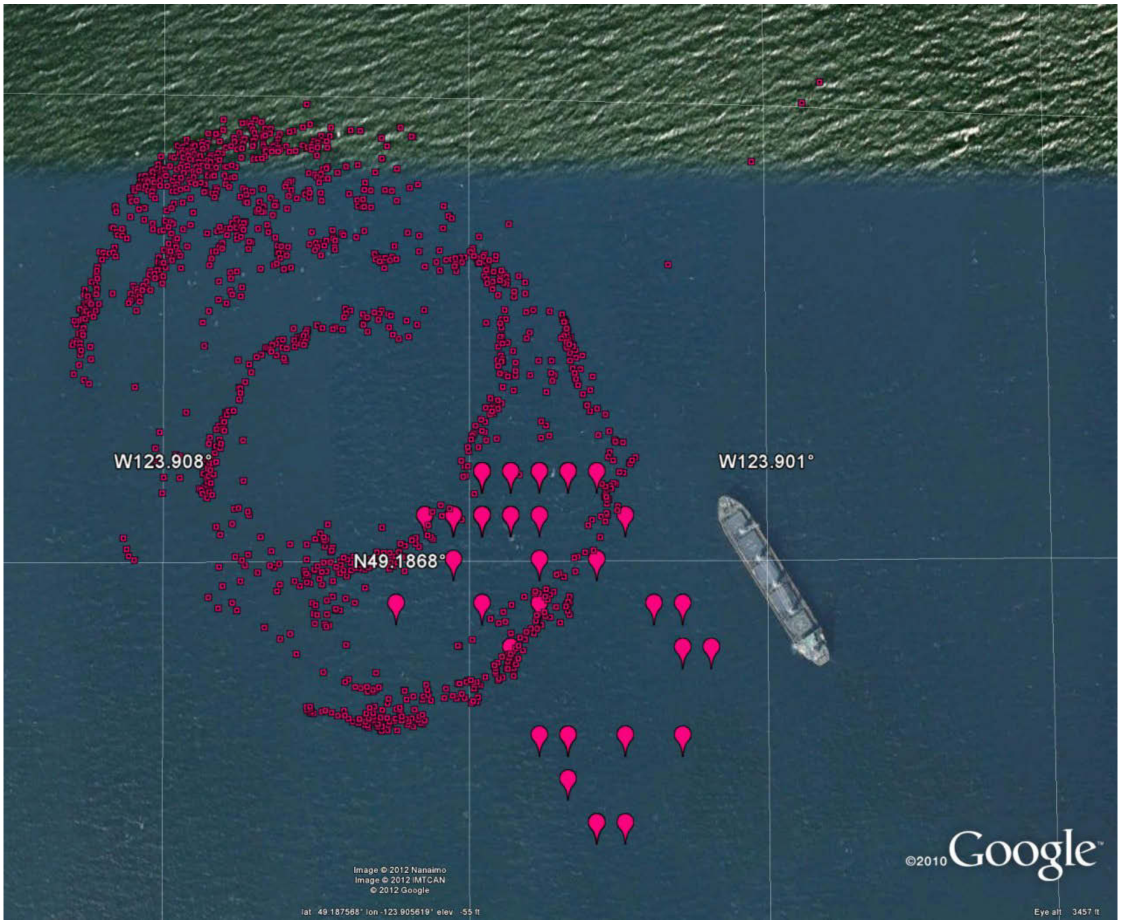

Figure 15: Positional data for a vessel from both AIS (overlapping pink squares) and LRIT (overlapping pink balloons). Note: The underlying image is a historical image from another date.

The final image (Figure 16) is of the same vessel as in Figure 15, but the ship is in transit. It can be seen in this location, and others, that the LRIT is somewhat offset from the AIS reports, while the AIS reports show little deviation from a line. It should be pointed out prior to analysing this figure that we cannot compare the time stamps of AIS messages and LRIT position reports to calculate the true spatial offset from near simultaneous transmissions. This is because the two systems timestamp differently. The MSSIS AIS timestamp does not indicate the broadcast time. Despite that, it is clear that LRIT and AIS positional information does not always line up. The offset in this figure is approximately 696 m from the LRIT position report to the AIS report that is closest in time, given that a better estimate is not available. Anecdotal evidence given here suggests that the AIS position might be truer. The offset varies quite dramatically within the examples given here. It seems clear that an LRIT position has some error associated with it, besides the error inherent in GPS that AIS positions clearly exhibit, assuming no systematic error on the part of Google Earth reading the positions.

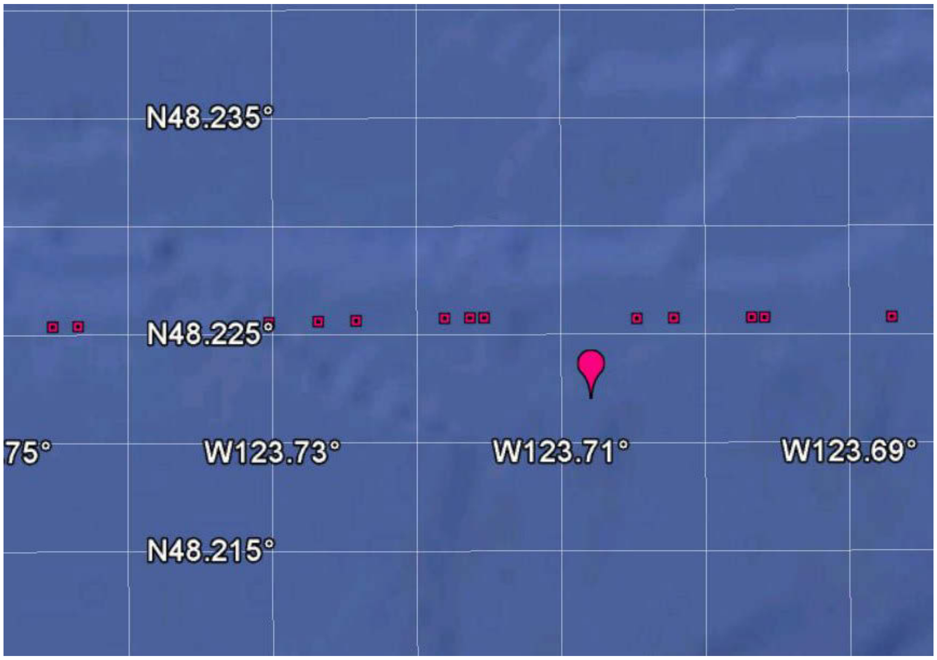

Figure 16: Positional data for a vessel from both AIS (13 pink squares) and LRIT (1 pink balloon). Note: The underlying image is a historical image from another date.

2.6.2 Who is reporting what

To compare AIS and LRIT reporting, an analysis was first done on the AIS broadcasts, on a day by day basis, looking for the day with the smallest AIS reception extents, i.e., the day that AIS messages were received from the smallest geographic area in the area of interest. The reasoning behind looking for the smallest AIS reception extents was that if both AIS and LRIT were being transmitted by a vessel in that area, the AIS broadcast had a good chance of being received on all days of the month within those limits. The smallest AIS reception extents happened on October 11. This was used as the area of interest for the remainder of the analysis. Figure 17 shows the corners of the area of interest. Both the LRIT data and AIS data were filtered to find reports transmitted within those limits.

Note that while the area of interest has been set at the smallest AIS reception extents, there may still be areas within that rectangle that the shore-based AIS receivers do not cover. These are called blank zones. It was reasoned that since the analysis is being done over the entire month, it would be unlikely that an LRIT and AIS broadcasting vessel might travel through one of these blank zones without travelling through an area with AIS coverage during the month. Based on this reasoning, no further refinement of the area of interest took place.

Figure 17: Area of interest. The pink stars signify the corners of the area of interest. The area of interest is located in the Pacific Ocean, including the Juan de Fuca Strait.

As mentioned in 2.3.1, MMSI numbers for a ship station identity is 9 digits. The first three non-zero numbers in an MMSI number represent a country (or base area) and are called a MID: Maritime Identification Digits. A country can have multiple MIDs assigned to them. The MID is a convenient parameter to use to analyse LRIT and AIS reporting, since country name variance becomes less of an issue. That being said, two vessels in the LRIT data set had MMSI numbers with MIDs that did not match a MID in the International Telecommunications Union's list of MIDs [16] and one MMSI number was negative. The bar charts that follow will have the country or base area along the vertical axis, rather than the actual MID. Some countries will therefore be represented multiple times due to multiple MIDs representing a single country.

There are three combinations of reporting that will be examined here: vessels reporting both AIS and LRIT during the month, vessels reporting only AIS and vessels reporting only LRIT. Within those combinations, the added parameter of whether the vessel is moving or not can be incorporated. Here are the facts (for the area of interest):

- 1089 transmitting vessels,
- 220 had the Canadian MID,
- 415 had a MID from the USA (sum of vessels with MIDs for the USA and Alaska), and
- 454 vessels had foreign MIDs (i.e., neither USA or Canadian).

North American vessels dominate the vessels in the area during that month but as a whole, 42% of the vessels reporting are foreign (from a Canadian plus USA perspective), which is a significant portion of the vessel traffic. Note that for the remainder of this section foreign refers to non-Canadian and non-USA vessels.

2.6.2.1 Reporting both LRIT and AIS data

In this section we examine vessels reporting both LRIT and AIS within the area of interest during October 2010:

- 341 vessels of the 1089 vessels in the area of interest transmitted at least one LRIT and one AIS transmission during the month,
- Of the 220 vessels with the Canadian MID, only 2 transmitted both AIS and LRIT,
- Of the 415 vessels with an American MID, only 34 transmitted both AIS and LRIT, and
- 305 foreign vessels were transmitting both AIS and LRIT, which indicates 149 foreign vessels were not transmitting both during the month.

Since vessels on domestic journeys are not required to transmit LRIT, and the area of interest covers both Canadian and American waters, the low numbers of Canadian and American vessels broadcasting both AIS and LRIT are not surprising. What is interesting is the high number of foreign vessels *not* broadcasting both AIS and LRIT.

As illustrated earlier, if a vessel should broadcast LRIT, it very likely needs to be broadcasting AIS as well. Figure 18 and Figure 19 show bar charts of the breakdown of LRIT and AIS broadcasts with respect to MID country/region. Figure 19 is merely a close-up of Figure 18, since vessels from the United States and Canada dominate this area of interest and make it difficult to extract information about other countries. The figures show that foreign countries often have vessels that broadcast just AIS (i.e., red), AIS and LRIT (i.e., blue) and occasionally only LRIT (i.e., green). If you count foreign country MIDs that exclusively have vessels that broadcast LRIT and AIS, it is found that there are twelve MIDs during the month. All other MIDs have a mixture of the possible combinations. In the following subsections, vessels only broadcasting AIS or only LRIT are discussed and analysed to better understand this observation.

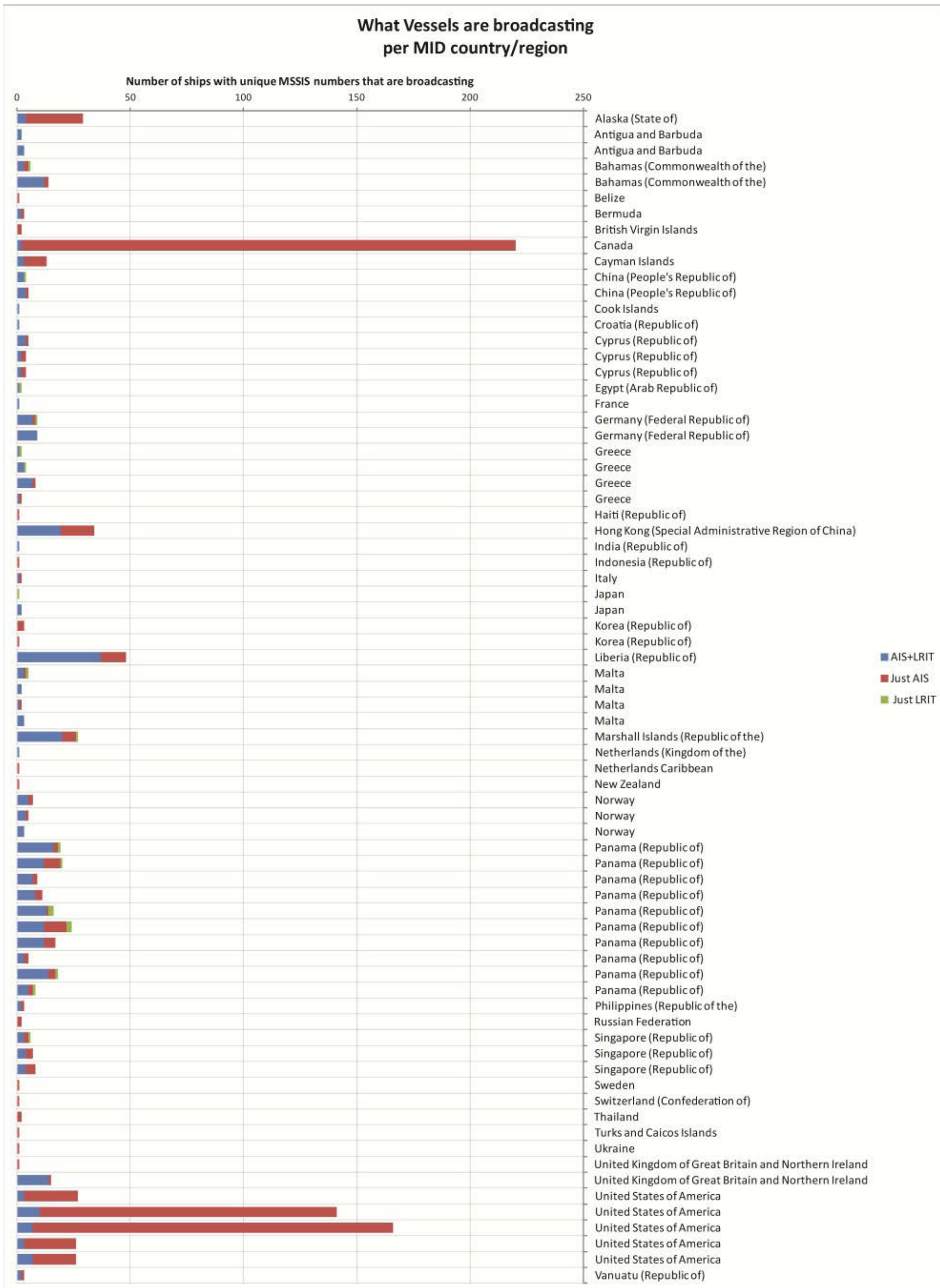

Figure 18: Bar chart of the breakdown of LRIT and AIS broadcasts with respect to MID country/region in the area of interest. The MID number is replaced by the country/region that it represents. Blue bar: vessels that transmitted both AIS and LRIT information during the month. Red bar: vessels that broadcast only AIS during the month. Green bar: vessels that transmitted only LRIT information during the month. The stacked bars cumulatively account for all vessels transmitting a particular MID during October 2010 in the area of interest.

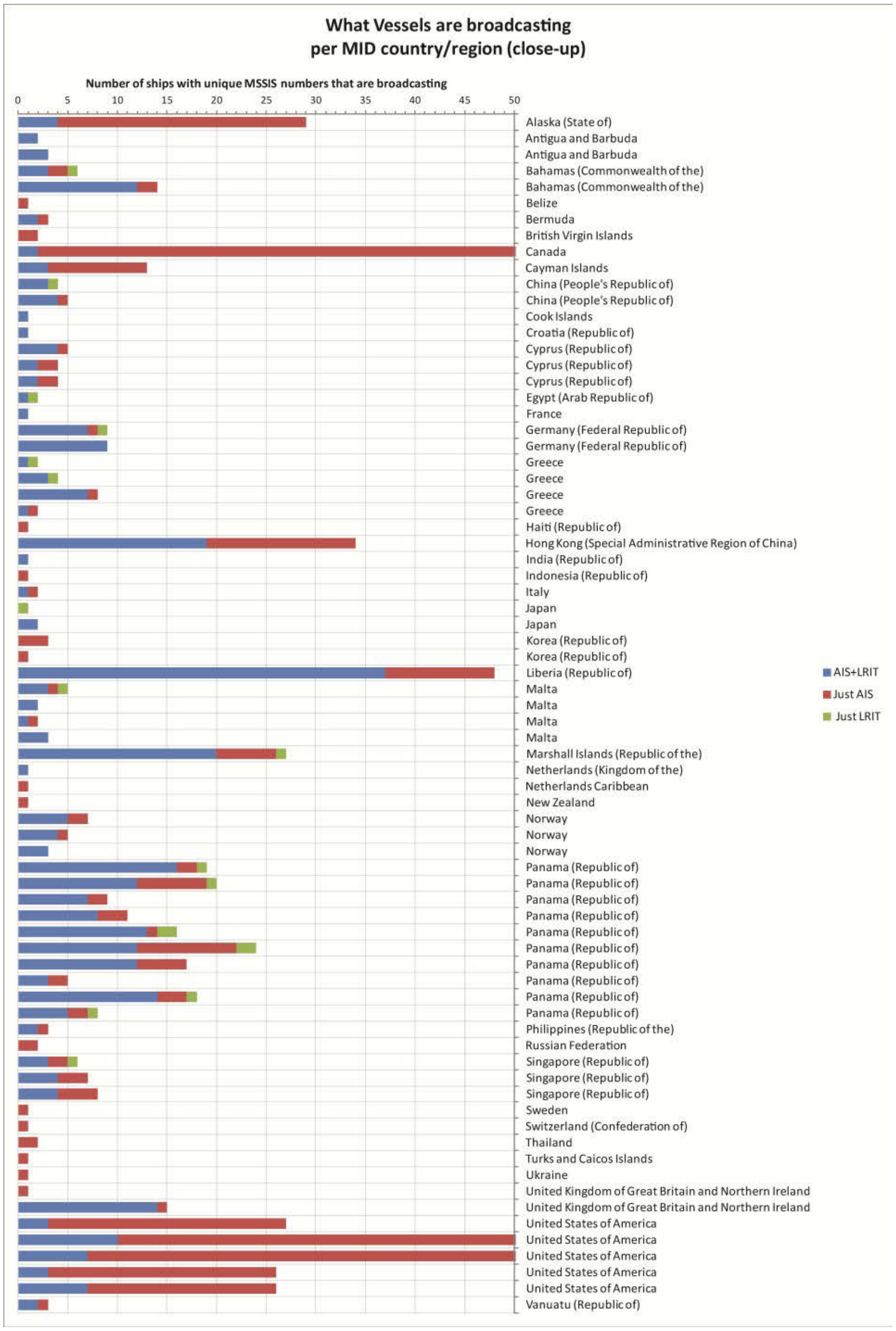

Figure 19: A close-up of Figure 18. Blue bar: vessels that transmitted both AIS and LRIT information during the month. Red bar: vessels that broadcast only AIS during the month. Green bar: vessels that transmitted only LRIT information during the month. The stacked bars cumulatively account for all vessels transmitting a particular MID during October 2010 in the area of interest. Note: the close-up obscures Canada and the USA.

2.6.2.2 Reporting only AIS data

In this section we examine vessels reporting only AIS within the area of interest during October 2010:

- 730 vessels only broadcast AIS,
- 9 instances where only one AIS message was received from a vessel,
- 218 of the 220 Canadian vessels only broadcast AIS,
- 381 of the 415 USA vessels only broadcast AIS, and
- 131 foreign vessels only broadcast AIS.

It was unanticipated that 131 of the 436 foreign vessels would be broadcasting just AIS. Given the SOLAS LRIT regulations, it is likely that these vessels should be broadcasting LRIT reports as well. However, there are possible explanations for this lack of LRIT transmissions:

- the vessel has been in the area of interest for less than 6 hours,
- the vessel is too small to require LRIT broadcasts,
- the SOLAS regulations do not apply to the vessel,
- the vessel was in American inland waters for the entire month, and
- the vessel is not technically on an international voyage because it is not underway during the month, going from one port to another.

First, whether vessels were underway was examined. It was determined which vessels broadcasting AIS move during the month by assessing if the maximum and minimum latitude and longitude variations were larger than 0.0025° and 0.0025° during the month. The criteria were arbitrarily chosen to be indicative of how much a vessel might drift while at anchor. If a vessel was assessed to be moving, the vessel was deemed to have been underway during a part of the month and therefore would qualify as being on an international voyage. Figure 20 shows a summary of the previous bar charts, though now distinguishing when a ship was detected to be moving or not moving (using the AIS data). If a colour bar is plotted, it means at least one vessel from that country met the legend criteria. There is one country, and only one instance where a vessel does not qualify to be underway during the month, yet is broadcasting LRIT (red bar). It can be seen that many foreign countries have at least one vessel just reporting AIS while we assume they were underway at some point during the month (green bar). The analysis concluded that:

- 655 vessels just broadcasting AIS were deemed to be underway during part of the month (a vessel that only broadcast once was assumed to be underway),
- 75 vessels broadcasting just AIS were determined not to be moving during the month. and
- 118 foreign vessels just broadcasting AIS were deemed to be underway during the month, which means 13 were deemed to be not underway during the month.

Therefore, 118 foreign vessels are not broadcasting LRIT but appear to be underway at some point in the month.

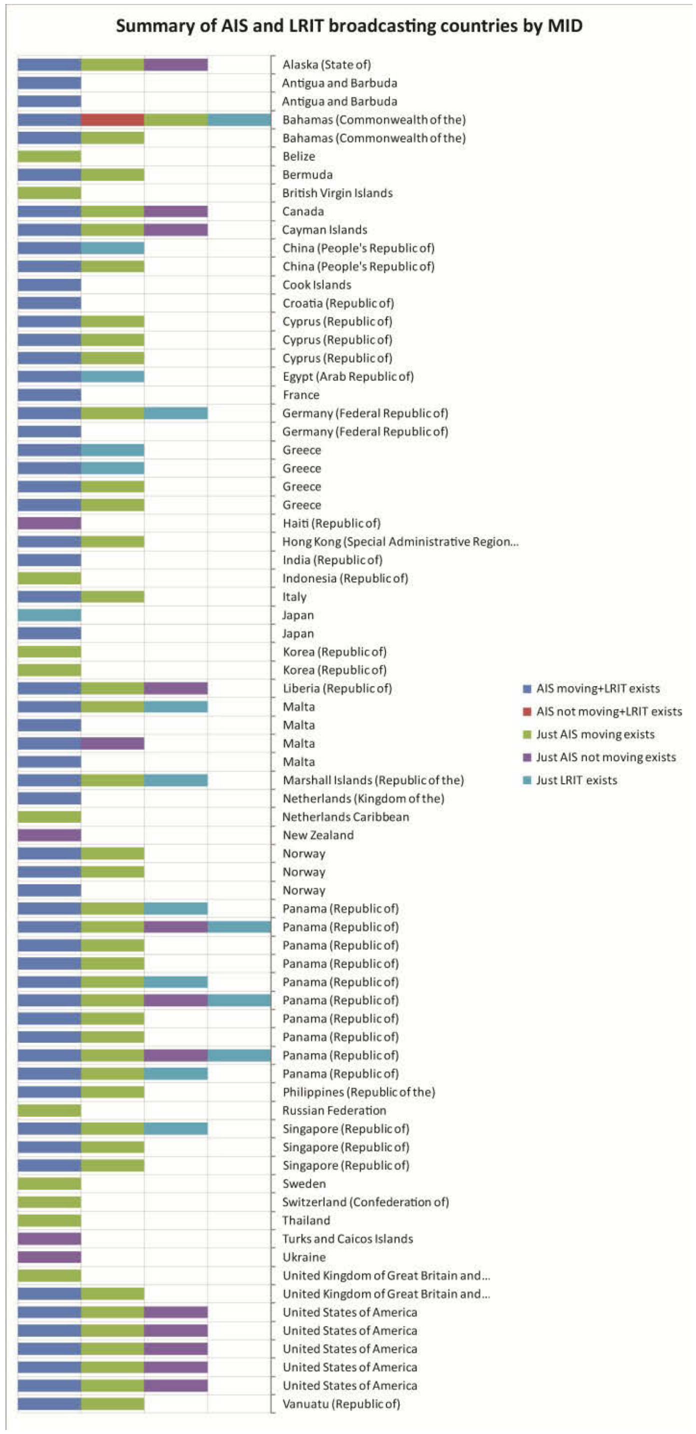

Figure 20: A summary of Figure 18, now distinguishing when a ship was determined to be moving or not moving, as determined by AIS. If a colour bar is plotted, it means at least one vessel from that country met the legend criteria.

The next tactic was to investigate some of the vessels to see if they satisfy another criterion for not broadcasting LRIT. A cursory investigation was undertaken to determine whether these vessels are correctly broadcasting only AIS. Thirteen vessels were randomly picked and plotted in Google Earth. One vessel was immediately discarded because it was clear it was not in the area of interest for more than 6 hours during the month. Of the remaining twelve, two did not appear to require LRIT. Figure 21 shows these two vessel tracks. The orange track that starts at a Canadian port is for a vessel that reports to be a pleasure craft. According to marinetraffic.com it is a sailing vessel that is 44 m by 10 m. Its IMO number is listed as zero but it has an MMSI number that coincides with the flag reported in marinetraffic.com. Nothing about this vessel suggests it should be broadcasting LRIT. The second vessel, indicated with the red circles in Figure 21, is completely in USA inland waters; therefore, Canada should not be receiving LRIT broadcasts. However, its MMSI number contains a valid MID followed by six 0s. The numeric composition suggests this is an invalid MMSI number.

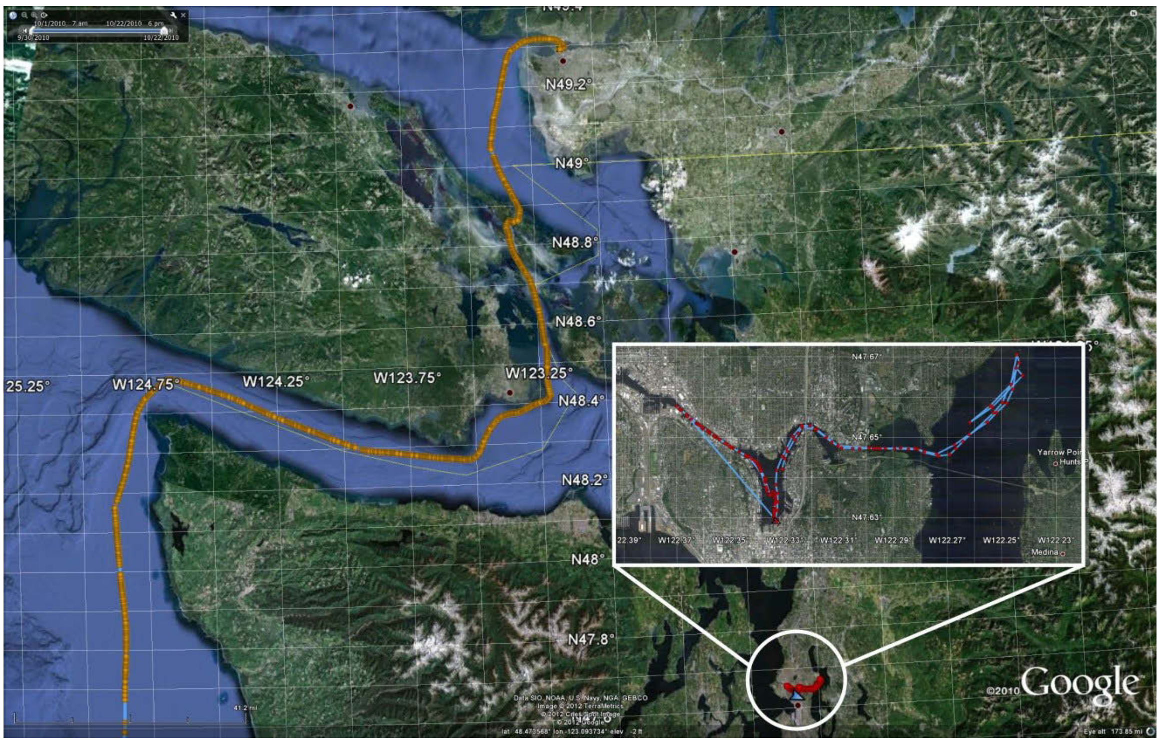

Figure 21: Example of two vessel tracks that are broadcasting AIS but Canada is rightfully not receiving LRIT information for. The orange track that starts at a Canadian port is for a vessel that appears to be a pleasure craft. The vessel indicated with the red circles, is completely in USA inland waters.

Canada appears to need to receive LRIT from seven vessels of the twelve, as shown in Figure 22. They are all within the area of interest, which is within the 1000 nm limit. As indicated by the tracks, if these vessels dock during the month they dock in Canadian ports. They are all in the area of interest for more than six hours. Based on size characteristics and the definition of a cargo vessel they all should be broadcasting LRIT and Canada should be receiving those broadcasts.

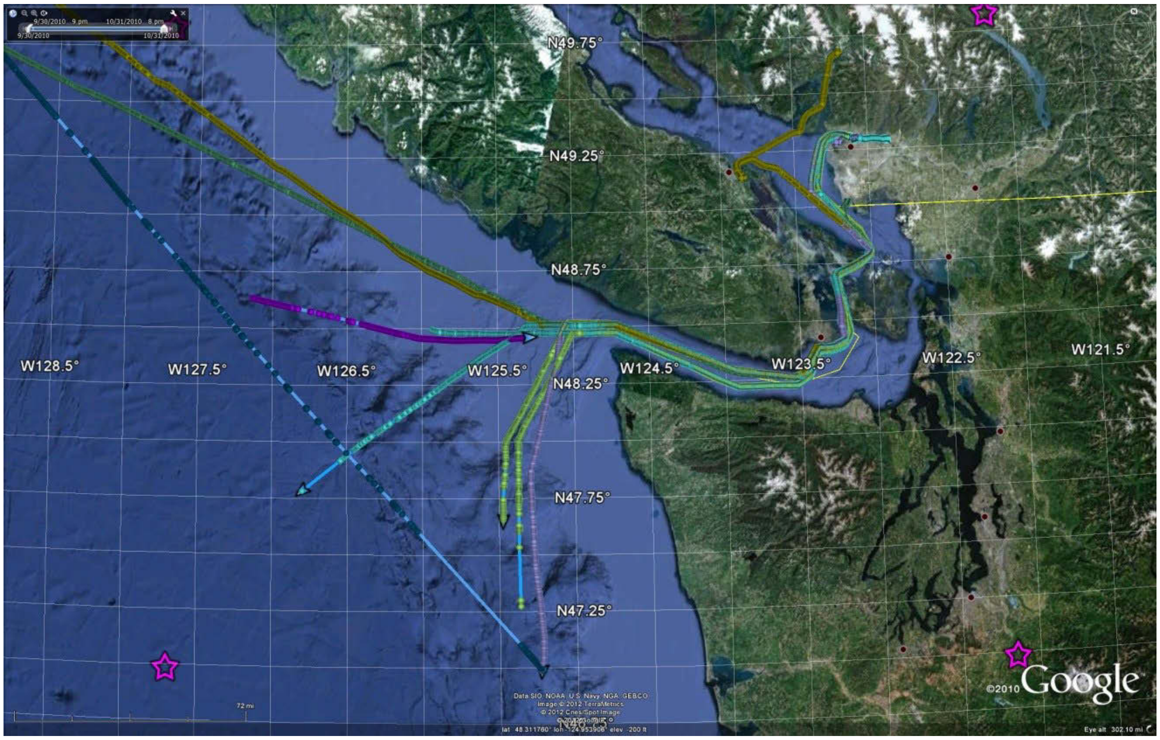

Figure 22: Example of seven AIS vessel tracks for foreign vessels. Indications are that Canada should receive LRIT information for these vessels. Each colour represents a different vessel.

Similarly, three of the twelve vessels should be broadcasting LRIT during the month, though there would be times for each of these vessels when Canada would not receive the broadcasts. Figure 23 shows the vessel tracks. Canada would cease receiving LRIT broadcasts when the vessel was in USA inland waters, but while outside those waters, Canada would have the right to receive the broadcasts.

In summary, 3 vessels legitimately did not broadcast LRIT: one had not been in the area of interest for more than 6 hours, one was a pleasure craft and one was in American inland waters the entire time. Canada should have received LRIT broadcasts for the other 10 ships for some of the month.

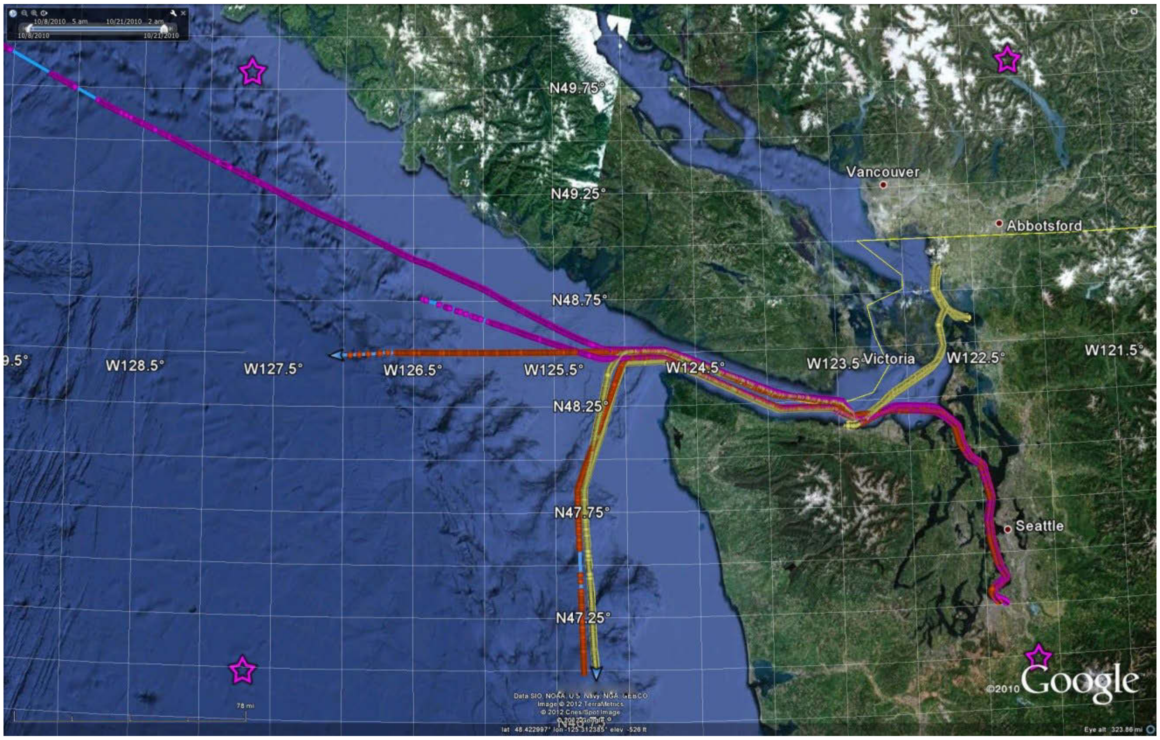

Figure 23: Example of three AIS vessel tracks for foreign vessels. Based on this examination, Canada should be receiving LRIT information about these vessels; but did not. Each colour represents a different vessel.

2.6.2.3 Reporting only LRIT data

In this section we examine vessels reporting only LRIT within the area of interest during October 2010:

- There were 18 (foreign) vessels that just broadcast LRIT, and
- Of the 18, there were 7 instances where only one LRIT report was received. Of these, 6 instances did not occur on a day that was the first or last of the month. (If it occurred on the first or last day of the month, that could explain a single report anomaly.)

The fact that there were 18 vessels that broadcast LRIT but not AIS is interesting. Section 1.3 indicates that the only time a vessel would be mandated to broadcast LRIT but not mandated to broadcast AIS would be if it is a mobile offshore drilling unit on an international voyage. A vessel outside of the AIS receiver limits would also appear to be only broadcasting AIS. The countries those 18 vessels belonged to are the Commonwealth of the Bahamas, the People's Republic of China, the Arab Republic of Egypt, Germany, Greece (2 vessels), Japan, Malta, the Republic of the Marshall Islands, the Republic of Panama (8 vessels), and the Republic of Singapore. If enforcing AIS compliance were an issue, this would be an easy way to get vessel names that are not complying. After confirming the vessel was neither a mobile offshore drilling unit nor consistently outside an area where AIS reception can be achieved, a list of vessels that are not complying with AIS regulations could be compiled. Subtracting out the 7 vessels that only

broadcast LRIT once would likely be prudent in this situation since they appear to be anomalies and not directly related to AIS compliance.

2.6.3 Does using both LRIT and AIS data offer redundancy?

Using both AIS data and LRIT data does add a certain redundancy to the picture. An anecdotal example is in Figure 24. This vessel was used as an example earlier in this paper (Figure 11). Canada started to receive LRIT reports for this vessel after it crossed the 1000 nm limit up near Alaska on October 5. On October 6, Canada stopped receiving LRIT reports for this vessel until October 14 when Canada started receiving reports from it again as it sat, docked, near Delta, British Columbia. However, as evident in the figure, AIS messages were received from the vessel long before it docked in Delta (the tight line of pink circles). In a situation where both AIS and LRIT reports are expected to be received, such as where the AIS messages were received in this example but not the LRIT reports, the system still receiving reports (in this case AIS) does offer some redundancy.

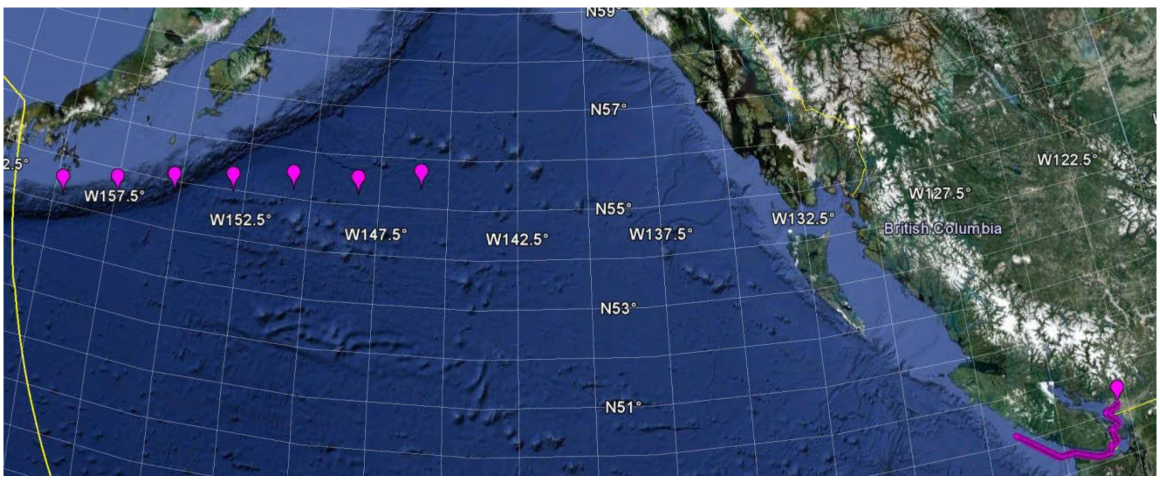

Figure 24: LRIT position reports and AIS message positions for a foreign vessel that transited into Canada's 1000 nautical mile limit near Alaska. Pink balloons represent LRIT information and pink circles represent AIS information.

2.7 Maritime Situational Awareness (MSA)

2.7.1 When added to AIS, how can LRIT enhance MSA?

Maritime Situational Awareness (MSA) can definitely benefit from using both AIS and LRIT. To use the redundancy example of the previous section, if only LRIT had been available, the first few days of tracking the vessel would look like Figure 25.

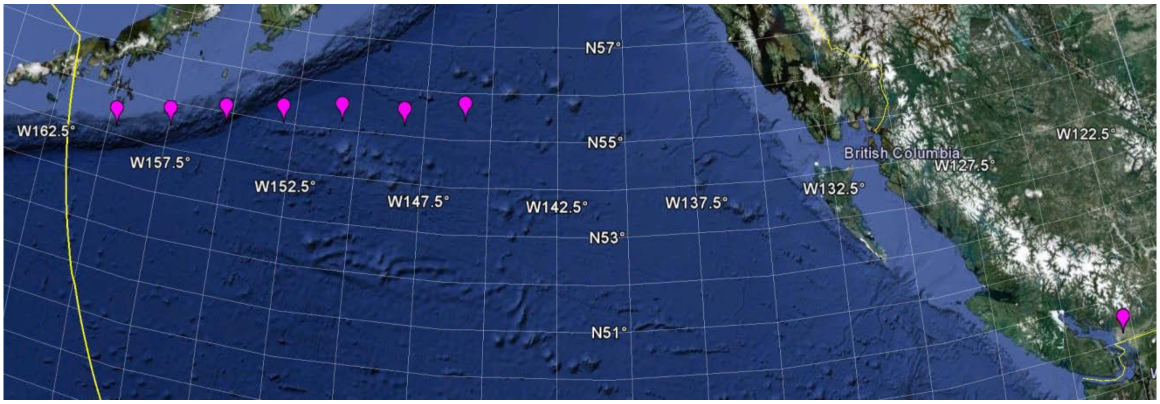

Figure 25: LRIT position reports for a foreign vessel that transited into Canada's 1000 nautical mile limit near Alaska and docked near Delta, British Columbia. Pink balloons represent LRIT information.

Awareness of where this vessel was for 8 days would have been lost for a reason that is not apparent from the data alone. In addition, if it had been broadcasting during those days, there would be no information about the vessel between the 6 hour broadcasts. While this may be sufficient while at sea, upon reaching territorial waters (e.g., such as 6 hours off the coast) increased reporting rates may be beneficial. In addition, as pointed out earlier, AIS is required for a greater number of vessels, therefore, even if LRIT was working perfectly all the time, there would be many vessels not broadcasting LRIT.

Figure 26 shows the AIS track for the same period of time, without the LRIT data.

Figure 26: AIS message positions for a foreign vessel that transited into Canada's 1000 nautical mile limit near Alaska and docked near Delta, British Columbia. Pink circles represent AIS information.

If these were the land based AIS receivers being used to achieve MSA, awareness of this vessel through AIS would not have been achieved until October 11, while with LRIT awareness of the vessel was achieved October 5th and at a much further distance from its destination than with AIS. On the positive side, the AIS information gives a much denser track than the LRIT at a proximity to land where it might be appreciated from an MSA point of view.

Therefore, AIS and LRIT can be seen to both have strengths and weaknesses. Better MSA will be achieved by using them both. Using only one will create gaps in information that is needed to build MSA.

2.7.2 Should LRIT reporting intervals be shortened to improve MSA?

This answer mostly depends on the proximity of the vessel to a country and the extent of AIS reception capability in the area of interest. When a vessel is days from the coast of a country, 6 hour intervals are likely sufficient. If AIS is unavailable, once the vessel is less than 6 hours from the coast and while in inland waters, an interval smaller than 6 hours would be useful to maintain awareness of the vessel. However, if AIS receptions are picking up the vessel in a reliable manner once it is within 6 hours of the coast, 6 hour intervals are likely still sufficient.

2.7.3 Would there be any value to incorporate LRIT into the visual representation of AIS reception characteristics?

AIS was intended to improve safety at sea. As such, the design of the system does not place priority on message reception from distances beyond those that would be important to collision avoidance. However, AIS messages can be received beyond 10’s of nautical miles. Spatial fluctuations exist in message reception, which are dependent partly on environmental factors. As a result, one needs to understand likely reception distances for coastal receivers.

Work has been done in the past on AIS reception distances [8]. This work focuses on visually representing reception characteristics of AIS ashore receivers which can change on a daily, even hourly, basis.

The merging of LRIT messages into the algorithm that creates the visual representation of AIS was considered to give a general reception index map for maritime domain awareness purposes. However, this would not be appropriate for the reception product. The product captures and visualizes the variations of AIS reception that are largely due to the local environment. LRIT is not affected by similar environmental influences. LRIT reports are transferred, most commonly, via satellite from anywhere in the world, and should have little to no variation due to local environmental conditions. As a result, incorporating LRIT would mix one product that is influenced by the environment, with a second product that has no environmental influence.

However, given the LRIT message characteristics, overlaying individual LRIT reports on the visual representation of the AIS extent described in [8] could have benefits. One benefit would be to catch those rare vessels only broadcasting LRIT and not AIS. By overlaying individual LRIT report positions on the AIS reception characteristic visualization, one could see areas from where the vessel’s AIS reports should be received. If AIS messages for those LRIT broadcasting vessels were not received, then investigation into why they are not being received could be performed.

This could be used to detect non-compliance of AIS broadcasting in real time rather than doing a historical analysis. Similarly, if a vessel broadcasting both AIS and LRIT stops broadcasting AIS in an area from where AIS messages should be received, and someone is alerted to this fact, an interested party could request an LRIT position report be sent. If there is no LRIT position report or the report is from an odd geospatial position, then this could alert the interested party that there is a situation that needs to be further investigated.

3 Concluding remarks

The main findings of this analysis were

1. In October 2010, LRIT pre-scheduled reports were not 100% reliable: they could be late, missing, occur more often than required, or have incorrect/missing information. Given that the data set was from the initial operating phase of the LRIT system, this is not surprising and could almost be expected.

2. LRIT and AIS data are complementary.

3. LRIT and AIS data offer only minimal redundancy.

4. To a certain extent, AIS and LRIT can be used to identify vessels that are non-compliant in transmitting either AIS or LRIT.

5. Where a country is not receiving coastal AIS messages, they may consider increasing the reporting rates of LRIT broadcasting ships once they are within 6 hours of the coast.

These findings give a clearer understanding of LRIT data and its relationship to AIS data to those working at improving MSA.

3.1 Summary

The following is a summary of some of the observations, conclusions and remarks made in this paper for the October 2010 data:

- There are 83666 LRIT position reports time stamped within October 2010 (Zulu) in the dataset that was used. There are around 2700 unique vessels in the dataset though an exact number is difficult to know with conflicting unique ship identifiers, and errors in the information.
- There is incorrect information in the LRIT data, such as the reported IMO numbers, MMSI numbers and names. This is occurring at the input source.
- Only 2% of LRIT reports have time stamps with non-zero second values. This suggests that either the onboard LRIT reporting system generally transmits exactly on the 0th second or that most time stamping is only accurate to the minute. AIS messages can be broadcast every 2 seconds under certain circumstances, which suggest there could be 60 AIS messages within +/- 1 minute of the LRIT timestamp, if it is only accurate to the minute.
- As is expected from the LRIT rules, there is a noticeable limit to the LRIT position reports at the 1000 nautical mile boundary. Canada also received LRIT position reports from foreign vessels beyond its 1000 nautical mile boundary but within its 2000 nautical mile boundary, the limit when a Notice of Arrival has been sent. However, Canada also received position reports from foreign vessels well beyond its 2000 nautical mile boundary.

- During October 2010, Canada did receive LRIT reports north of the Arctic Circle, the most northerly being approximately 81° North.
- Some monitoring of the LRIT pre-scheduled position reports is required to detect:
  - days when LRIT transmissions have not been received from a vessel that was previously transmitting,
  - position reports unrealistically geographically spaced,
  - consistently missing reports,
  - vessels periodically reporting at intervals larger than 6 hours,
  - vessels consistently reporting more often than has been requested, and
  - vessels periodically reporting more often than has been requested.
- What was found in this study concerning missed reports is consistent with what was reported by the European Commission at the 10th Ad Hoc LRIT Group in September 2011 [15].
- Further investigation is necessary to determine why the reported LRIT positions were geospatially offset from the reported AIS positions. If it is not an artefact introduced into the data set (such as value conversion or round-off errors), the users need to determine whether or not this offset is acceptable.
- Checking to see if foreign vessels that are only broadcasting AIS should also be broadcasting LRIT is time intensive and repetitive to do by hand. An algorithm could be implemented that could automatically check all possible reasons why they are not broadcasting.
- AIS and LRIT should be used together because they complement each other's strengths. For example, the reporting frequency of AIS near the coast may be more appropriate for monitoring ships than getting LRIT reports every 6 hours. Conversely, if AIS coverage is not constantly available in open ocean, which is a limitation seen in land based AIS receivers, LRIT gives information on ships traversing through that area at a time scale appropriate for the situation. The two systems also offer a certain amount of redundancy if one becomes unavailable.
- In coastal areas without AIS coverage, it might be beneficial to increase the LRIT reporting rate to improve MSA.
- Comparing the location of vessels only reporting LRIT to areas of known good AIS reception could help identify vessels that are not complying with AIS broadcast rules.

3.2 Future analysis

- Doing a similar analysis with, a larger LRIT data set, from a time after the initial LRIT implementation would be useful for identifying characteristics that were specific to that initial LRIT implementation stage. In addition, using raw AIS messages rather than data collected from MSSIS would be a more accurate comparison.

- Doing a similar analysis with a large LRIT data set compared to an equivalent S-AIS data set would also yield some interesting and useful results.

3.3 Future work: Information products

The following are information products that could be developed to identify when ships are not adhering to AIS and LRIT rules:

- Develop a product that uses AIS static information to determine if the vessel should also be broadcasting LRIT. If it should be broadcasting LRIT, steps can then be taken to notify the interested party.
- Develop a product that triggers a database search of a vessel if it is only broadcasting LRIT in an area covered by AIS receivers, to determine if it is adhering to the AIS broadcast rules.
- Develop a product that generates a map every 6 hours or the last known position of all ships that missed their last LRIT pre-scheduled position report. By geographically displaying the data, it becomes easier to ignore vessels that are no longer in an area from which their reports should be received. Queries can be made about the vessels that appear to have stopped reporting.

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List of symbols/abbreviations/acronyms/initialisms

AIS	Automatic Identification System
ARP	applied research project
ASP	Application Service Provider
CCG	Canadian Coast Guard
CDC	Cooperative LRIT Data Centre
CSP	Communication Service Provider
DRDC	Defence Research & Development Canada
EU	European Union
IMO	International Maritime Organization
LRIT	Long-Range Identification and Tracking
MDA	Maritime Domain Awareness
MMSI	Maritime Mobile Service Identity
MSA	Maritime Situation Awareness
MSSIS	Maritime Safety & Security Information System
NDC	Canadian LRIT National Data Centre
R&D	Research & Development
SEDNA	Situational Information for Enabling Development of Northern Awareness
SOLAS	Safety of Life at Sea

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There have been amendments in the recent decade to Chapter V of the 1974 International Convention for the Safety of Life at Sea (SOLAS) which is concerned with Safety of Navigation. One amendment addressed collision avoidance, with the result being the automatic identification system (AIS). Another amendment addressed the identification and tracking of vessels at longer distances, with the result being the long-range identification and tracking (LRIT) system. The two systems have different purposes, but within those purposes they do provide similar information. The goals of this report include a better understanding of LRIT data, an understanding of how AIS and LRIT information complement each other and how combining AIS and LRIT information can improve maritime situational awareness. The AIS position information was found to be offset from the LRIT position information. Identifying vessels that are only broadcasting either AIS or LRIT but should be broadcasting both could be used to enforce AIS and LRIT regulations. It was found that using both systems to achieve situation awareness only offers limited redundancy; however, the two systems do complement each other. In coastal areas where no AIS data are being collected, requesting the LRIT reporting rate be increased could improve maritime situation awareness. Several of the findings documented in this paper corroborate findings made by the LRIT working group.

Au cours des dix dernières années, des modifications ont été apportées au chapitre V de la Convention internationale de 1974 pour la sauvegarde de la vie humaine en mer (SOLAS), qui traite de la sécurité de la navigation. L'une des modifications portait sur les moyens d'éviter les collisions (évitement d'abordage); elle a donné lieu à la création du système d'identification automatique (SIA). Une autre modification portait sur la nécessité d'identifier et de suivre les navires sur de plus longues distances; cette modification a donné lieu à la création du système d'identification et de suivi à grande distance des navires (LRIT). Les deux systèmes ne jouent pas le même rôle, mais fournissent néanmoins des informations semblables. Le but du présent rapport est de mieux comprendre les données LRIT, de déterminer en quoi les systèmes SIA et LRIT se complètent et de trouver des façons de combiner l'information du SIA et celle du LRIT de manière à améliorer la connaissance de la situation maritime. L'information sur la position fournie par le SIA s'avère décalée par rapport à l'information sur la position fournie par le LRIT. L'identification des navires qui n'émettent que dans l'un ou l'autre des systèmes (SIA ou LRIT), mais qui devraient émettre dans les deux systèmes, pourrait servir à faire appliquer la réglementation sur le SIA et le LRIT. Il a été déterminé que l'utilisation des deux systèmes pour atteindre l'objectif de connaissance de la situation n'offre qu'une redondance limitée. Cependant, les deux systèmes se complètent l'un l'autre. Dans les zones côtières où aucune donnée SIA n'est recueillie, le fait de demander que la fréquence de transmission soit accrue pourrait améliorer la connaissance de la situation maritime. Plusieurs des résultats documentés dans le présent rapport confirment les résultats obtenus par le groupe de travail sur le LRIT.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g., Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

LRIT; Long-Range Identification and Tracking; AIS; Automatic Identification System; MDA; Maritime Domain Awareness; MSA; Maritime Situation Awareness; SOLAS; Safety of Life at Sea;

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